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WATER QUALITY IN THE CLARK FORK RIVER BASIN, MONTANA

STATE FISCAL YEARS 1988-1989

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Final Project Report to the
Resource Indemnity Trust Grant Program
Montana Department of Natural Resources and Conservation

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SUMMARY

Water Quality monitoring throughout the Clark Fork Basin during state fiscal years 1988 and 1989 provided information which will be invaluable in the management of the basin's natural resources. Sound decisions relating to Superfund activities, instream flow reservations, nonpoint source pollution control programs, wastewater discharge permits and other unforeseen development and pollution abatement activities will be possible given the availability of comprehensive water quality data. The impacts of those decisions can also be evaluated when an adequate baseline of information exists.

The drought conditions which predominated for much of the two-year period altered many of the attributes observed in previous years. Because streamflows were lower, suspended sediment and metals concentrations and loads were smaller. Nonpoint sources of nutrients were relatively less significant due to less erosion. Municipal and industrial discharges were relatively more important because of less instream dilution.

Silver Bow Creek continued to show severe degradation from heavy metals and nutrients. The Warm Springs treatment ponds effectively removed much of the suspended sediment, metals, and nutrients in Silver Bow Creek before discharging to the headwaters of the Clark Fork. In fact, treatment may have been more effective because of lower flows and longer retention times. The Mill-Willow creeks bypass contributed water of fair to poor quality to the Clark Fork, and nutrient and metals contamination was frequently evident. Warm Springs Creek, with its hard and usually good to excellent water quality was important in diluting metals concentrations in the Clark Fork headwaters. However, this stream was severely dewatered in the summer.

The Clark Fork from its headwaters to the Little Blackfoot River, exhibited persistent degradation from metals and nutrients. Some of the highest instantaneous metals concentrations were recorded in the upper end of this reach, while highest average metals concentrations occurred in the lower end. In addition, some of the highest nutrient concentrations anywhere in the mainstem Clark Fork were found downstream of Deer Lodge. Suspended sediment concentrations generally increased downstream through this reach.

Between the Little Blackfoot River and Missoula, numerous large clean tributaries gradually improved water quality, although phosphorous concentrations downstream to Rock Creek routinely exceeded criteria designed to prevent nuisance levels of algae. Heavy accumulations of filamentous algae were quite common upstream of Rock Creek. Exceedences of metals criteria were infrequent. Suspended sediment concentrations continued to increase downstream to Rock Creek.

Between Missoula and the Flathead River, the Missoula WWTP and the Stone Container Corporation discharges had major influences on water quality. The highest nutrient concentrations were found downstream of these discharges. However, filamentous algae were never common and algal growth consisted primarily of diatoms. The quality of the Stone Container Corporation discharge clearly reflected the nutrient reduction measures undertaken in the last few years. The Bitterroot River was shown to be a major contributor of nitrogen and suspended sediment to the middle Clark Fork. Occasional releases of sediment and heavy metals from Milltown Reservoir occurred during the reconstruction of Milltown Dam, although exceedences of water quality criteria were not measured.

Below the Flathead River, water quality was excellent. Exceedence of metals and nutrient criteria were rare. Sediment concentrations increased during spring runoff due to ice scouring in the lower Flathead River, but effects were short lived. The Thompson Falls, Noxon, and Cabinet Gorge Reservoirs appeared to be effective sinks for nutrients and sediment. The data indicated that the Flathead River contributed a larger cumulative load of total phosphorus and total nitrogen to the Clark Fork than any other source in the basin.

The Clark Fork Basin water quality monitoring project is expected to continue at approximately the same level of intensity until mid-1991, in conjunction with additional nutrient monitoring being conducted in the basin under Section 525 of the 1987 Clean Water Act Amendments.

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1. INTRODUCTION

1.1 Background

In late 1983, the Montana Water Quality Bureau unveiled a proposal to modify an existing wastewater discharge permit for the Champion International(now Stone Container Corporation) kraft mill at Frenchtown to allow year around discharge of effluent to the Clark Fork River. At the time, no one could have anticipated that this single event would act as the catalyst for sweeping changes in Montana's largest river basin. The Bureau's proposal created public outrage, prompted the formation of a powerful citizen's water quality lobby and drove home the fact that our knowledge of the river was inadequate for effective water quality management.

An immediate result was the initiation in 1984 of a comprehensive water quality study of the lower 230 miles of the Clark Fork. While that study and others answered many basic questions about the river, even more were raised. In view of a multitude of planned development and pollution abatement activities in the basin, and growing public interest in improving the river, the need for more information became apparent.

In late 1985, the Bureau applied to the Montana Department of Natural Resources and Conservation (DNRC) for Resource Indemnity Trust Grant Program (RIT) funding of a comprehensive water quality monitoring program for the entire Clark Fork River. Funding was approved by the 1986 special session of the Montana legislature. Subsequently, an application was submitted and approved for a two-year continuation of the program through state fiscal year 1989.

It's been a mere six years since the debate over the kraft mill began and the future of the Clark Fork Basin appears much brighter. The Montana Department of Health and the U.S. EPA have made the Clark Fork a priority waterbody. Sewage treatment plants have been upgraded and their effluents improved. The kraft mill has a new discharge permit and a better quality effluent which provides increased protection for the river and its uses. The Superfund program was initiated in the Clark Fork Basin and cleanup of historic mine wastes in the headwaters may begin as soon as next summer. State agencies have applied for reservations to guarantee minimum instream flows. New nonpoint source water pollution control programs are inventorying diffuse, land use-related sources of pollution in the basin. And Congress, under Section 525 of the 1987 federal Clean Water Act Amendments, has mandated a three-year, three-state investigation of water quality problems in the entire Clark Fork-Pend Oreille Basin, with a goal of developing a comprehensive water quality management plan. The Water Quality Bureau's basin-wide monitoring data have played a part in all of these actions.

Indeed, their value will be even greater in the future, as new development activities arise and as pollution abatement projects continue to improve the quality of the Clark Fork River.

This report describes the Water Quality Bureau's Clark Fork Basin water quality monitoring program and provides a characterization of water quality conditions in the basin for the period from July 1987 through June 1989 (state fiscal years 1988-1989). Evaluations of biological conditions in the river basin, conducted as part of this program, are the subject of separate, accompanying reports (Bahls, 1989; McGuire, 1989a, 1989b).

1.2 Hydrologic Characteristics

The Clark Fork is Montana's largest river and a tributary to the Columbia River system. Originating from the flows of Silver Bow and Warm Springs creeks in the Deer Lodge valley of west central Montana, the river drains nearly all of Montana west of the Continental Divide and a small part of northern Idaho. The basin is bounded by the Continental Divide on the east and south, the Montana-Idaho state line on the west and the Flathead River - Clark Fork divide to the north. The total drainage area exceeds 22,000 square miles. From its headwaters, the Clark Fork flows in a primarily northwesterly direction for about 350 river miles to its terminus at Lake Pend Oreille in northern Idaho, approximately seven miles west of the Montana-Idaho border. The river flows through a variety of terrain, including broad, semi-arid valleys, high mountain ranges and steep-sided valleys.

The Clark Fork is often described in terms of upper, middle and lower river segments because the character of the river and the nature of the problems differ substantially from one area to another. The upper river segment is about 125 miles long and extends from the headwaters to below Milltown Dam. Streamflows in this reach range from an annual average of 319 cubic feet per second (cfs) at Deer Lodge to 3012 cfs below Milltown Dam (USGS, 1988). Major tributaries to the upper Clark Fork include Silver Bow Creek, Warm Springs Creek, the Little Blackfoot River, Gold Creek, Flint Creek, Rock Creek and the Blackfoot River. Most of the annual flow occurs during spring runoff, which is quite variable both in timing and volume (MDHES, 1975).

The middle reach of the Clark Fork extends for 120 river miles from below Milltown Dam to the confluence with the Flathead River. Streamflows in the middle Clark Fork average 7508 cfs at the downstream end of the segment (USGS, 1988). Major tributaries include the Bitterroot and St. Regis Rivers.

The lower Clark Fork begins at the confluence of the Flathead River and ends at Lake Pend Oreille in Idaho. Average

annual streamflows range from 19,860 cfs at Plains to 22,260 cfs at the Idaho border (USGS, 1988). Streamflows and the character of the lower Clark Fork are largely influenced by the presence of three mainstem hydroelectric facilities -- Thompson Falls, Noxon Rapids and Cabinet Gorge Dams. Important tributaries include the Flathead, Thompson, Bull and Vermilion rivers and Prospect Creek.

Additional information pertaining to climate, topography, geology, hydrogeology, soils, and land and water use in the Clark Fork Basin is available in a variety of sources including: Johnson and Schmidt, 1988; Johnson and Knudson, 1985; and MDHES, 1985, 1976, 1975.

1.3 Water Quality Problems

The Clark Fork River has been described as the most polluted watershed in Montana. This reputation is undeserved for much of the river's length and stems largely from the pollution problems of the headwaters region. Silver Bow Creek is perhaps the most degraded stream in western Montana and its quality more closely resembles an industrial or municipal wastewater than a Montana headwaters stream. Silver Bow Creek was recently reclassified to a Class I stream in the Montana Water Quality Standards (A.R.M., 1988) which reflects the state's goal to improve the quality of the stream to eventually support the following uses: drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

Silver Bow Creek currently cannot support most of these uses as a result of heavy metals pollution from former mining and mineral processing operations and inadequate dilution of the Butte municipal sewage discharge.

The upper Clark Fork has variable water quality classifications to reflect variable water quality conditions and problems. From its point of origin below Warm Springs Creek to Cottonwood Creek at Deer Lodge, the river is classified C-2, which means that it shall be maintained as suitable for bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply. From Cottonwood Creek to the Little Blackfoot River, the Clark Fork is classified C-1, which is similar to C-2 with "marginal" removed from the statement pertaining to the propagation of salmonid fishes and associated aquatic life. From the Little Blackfoot River to Milltown Dam, the classification of the Clark Fork improves to B-1, which specifies that C-1 uses shall be protected plus drinking, culinary and food processing uses after conventional treatment.

The Montana Water Quality Standards reflect generally improving water quality conditions in the upper Clark Fork with increasing distance from its headwaters region. However, the intended beneficial water uses are not always supported due to a variety of problems. The metals sources in the headwaters region and metals deposits in floodplains of the upper Clark Fork cause seasonal exceedences of criteria designed to protect aquatic life. Periodic fish kills have been documented above Deer Lodge. Nutrient additions from municipal sewage discharges promote the development of excessive quantities of filamentous algae and mid-summer dissolved oxygen levels occasionally fall below standards. Dewatering of the river for irrigation is an ongoing problem and summer water temperatures periodically exceed suitable levels for trout. The ground water adjacent to Milltown Dam has been contaminated with arsenic as a result of river-borne tailings which have been concentrated behind the dam.

The middle Clark Fork River has a water-use classification of B-1 for its entire length. The water quality of the middle river is much improved over the upper Clark Fork primarily as a function of dilution from large tributaries such as the Bitterroot River. The major water quality issue in this reach is the discharge of nutrients and other pollutants from sources such as the Missoula municipal sewage discharge and wastewater from the Stone Container Corporation (formerly Champion International) kraft mill. There has been a growing public concern over levels of algae in the middle river, which are stimulated by nutrient additions, and depressed mid-summer dissolved oxygen concentrations.

The lower Clark Fork, from the Flathead River to Lake Pend Oreille, is also classified B-1 for its entire length. Many of the water quality problems of the lower river segment stem from the streamflow manipulations created by the operation of the hydroelectric dams. There have also been concerns that the loading rates of nutrients from Montana sources are too high to protect the trophic status and character of Lake Pend Oreille and to prevent the proliferation of lake algae. The short reach of the Clark Fork from Cabinet Gorge Dam to Lake Pend Oreille is protected under the Idaho Water Quality Standards for the following uses: domestic water supply, agricultural water supply, cold water biota, salmonid spawning and secondary contact recreation -- which is comparable to Montana's B-1 class. A more complete description of environmental issues and water quality problems in the Clark Fork River Basin can be found in Johnson and Schmidt, 1988.

1.4 Monitoring Plan

In September 1985, the Water Quality Bureau initiated a comprehensive, basin-wide fixed-station water quality monitoring

program on the Clark Fork River. This program was a logical extension of the intensive two-year study of the lower 230 miles of the Clark Fork and of the monthly monitoring of a limited number of stations in the upper river which had been conducted since 1982. The new program sampled a greater number of water quality variables, and tied the two earlier monitoring networks together by adding stations in formerly unmonitored reaches. Noncritical stations were deleted in order to maintain the program at a manageable size.

The new program was designed to 1) characterize the long-term and cumulative water quality effects of resource development, and reclamation and pollution control efforts; 2) detect violations of ambient water quality standards; 3) monitor the biological health of the river; and 4) to provide data for water quality management decisions such as the issuance or reissuance of wastewater discharge permits.

While some changes in monitoring stations and water quality variables have been made since the program's inception in 1985, the program objectives and the monitoring approach have remained the same. The monitoring network utilized in 1988-1989 consisted of 32 fixed water quality monitoring stations on the Clark Fork River, its major tributaries and wastewater discharges, beginning on Silver Bow Creek at Butte and continuing to below Cabinet Gorge Dam in Idaho (Figure 1). Stations were selected to bracket known or suspected pollution sources, to track pollution concentrations with increasing distances from sources and to take advantage of existing U.S. Geological Survey (USGS) streamflow gaging stations for river discharge data (Table 1).

The monitoring approach consisted of water quality data collection approximately 16 times during each of the two years (generally monthly from July to the onset of spring runoff, followed by two to three samplings per month through June). No monitoring was conducted in February 1989 due to extremely cold weather and heavy ice formations at monitoring stations.

Variables routinely sampled for included the primary pollutants in the Clark Fork system -- metals, suspended sediment and nutrients (including ammonia). Macroinvertebrate and periphyton samples were collected once each summer (August) as a measure of the biological integrity at the various monitoring stations. The biological data are evaluated in separate reports (Bahls, 1989; McGuire, 1989a, 1989b). The monitoring activities, frequency and variables measured in fiscal years 1988-1989 are summarized in Table 2. The stations at which each monitoring activity was performed are shown in Table 3.

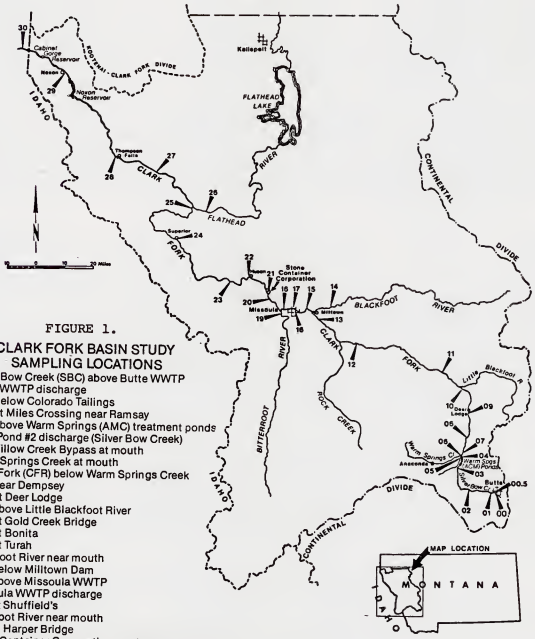

FIGURE 1.

CLARK FORK BASIN STUDY SAMPLING LOCATIONS

00 Silver Bow Creek (SBC) above Butte WWTP
00.5 Butte WWTP discharge
01 SBC below Colorado Tailings
02 SBC at Miles Crossing near Ramsay
03 SBC above Warm Springs (AMC) treatment ponds
04 AMC Pond #2 discharge (Silver Bow Creek)
05 Mill-Willow Creek Bypass at mouth
06 Warm Springs Creek at mouth
07 Clark Fork (CFR) below Warm Springs Creek
08 CFR near Dempsey
09 CFR at Deer Lodge
10 CFR above Little Blackfoot River
11 CFR at Gold Creek Bridge
12 CFR at Bonita
13 CFR at Turah
14 Blackfoot River near mouth
15 CFR below Milltown Dam
16 CFR above Missoula WWTP
17 Missoula WWTP discharge
18 CFR at Shuffield's
19 Bitterroot River near mouth
20 CFR at Harper Bridge
21 Stone Container Corporation wastewater discharge
22 CFR at Huson
23 CFR near Alberton
24 CFR at Superior
25 CFR above Flathead River
26 Flathead River near mouth
27 CFR above Thompson Falls Reservoir
28 CFR below Thompson Falls Dam
29 CFR below Noxon Rapids Dam
30 CFR below Cabinet Gorge Dam

Table 1. Clark Fork Basin Study Fiscal Years 1988-1989 Monitoring Station Descriptions

Station Number	Station Name	Legal Description	River Mile[1]	Average Annual Flow (cfs)[2]	Station Rationale
00	Silver Bow Creek above Butte wastewater treatment plant (WWTP)	T3N R8W Sec 23 DAD	-28.0	---	Metals problem from historic mining and smelting in headwaters. Control station above Butte WWTP.
00.5	Butte Metro WWTP discharge	T3N R8W Sec 23 DA	-27.5	7.6[3]	Large volume point-source municipal discharge to Silver Bow Creek
01	Silver Bow Creek below Colorado Tailings	T3N R8W Sec 22 ACA	-27.0	25.6	Station allows examination of effects of Butte wastewater discharge and Colorado Tailings on Silver Bow Creek water quality.
02	Silver Bow Creek at Miles Crossing near Ramsay	T3N R9W Sec 16 ACC	-17.0	---	Station is located below additional streamside tailings.
03	Silver Bow Creek at frontage road above AMC Warm Springs treatment ponds	T4N R10W Sec 02 DD	-6.0	---	Control station above Warm Springs treatment ponds.
04	Discharge from AMC Warm Springs Pond #2 (Silver Bow Creek)	T5N R9W Sec 19 BAB	-2.0	---	Station allows comparison of metals and other pollutants from above to below treatment ponds.
05	Mill-Willow creeks Bypass at mouth	T5N R9W Sec 19 BB	-2.0	---	Mill-Willow Bypass receives untreated Silver Bow Creek flood waters and contains streamside mine tailings deposits.
06	Warm Springs Creek at mouth	T5N R9W Sec 18 DBB	-0.5	---	Relatively clean tributary which, together with Silver Bow Creek, forms the Clark Fork.
07	Clark Fork below Warm Springs Creek	T5N R9W Sec 18 AC	0.0	---	Extreme headwaters of Clark Fork. Poor water quality from metals and nutrients.
08	Clark Fork near Dempsey	T6N R9W Sec 21 BBB	8.0	---	Continuing poor water quality and a declining fishery.

Table 1. Continued.

Station Number	Station Name	Legal Description	River Mile[1]	Average Annual Flow (cfs)[2]	Station Rationale
09	Clark Fork at Deer Lodge	T7N R9W Sec 09 BAB	21.0	319	Long-term monitoring station. Deteriorating water quality from streamside mine tailings. Control station above Deer Lodge municipal wastewater discharge.
10	Clark Fork above Little Blackfoot River	T9N R9W Sec 30 DA	36.0	---	Station allows examination of effects of Deer Lodge wastewater discharge and additional metals sources.
11	Clark Fork at Gold Creek Bridge	T10N R11W Sec 25 CBD	46.5	628	Station is located below the Little Blackfoot River.
12	Clark Fork at Bonita	T11N R16W Sec 10 DDC	96.5	935	Control station above Rock Creek. Depressed trout population.
13	Clark Fork at Turah	T12N R18W Sec 01 CBC	113.5	1400 (Est.)	Control station above Milltown Reservoir and test station below Rock Creek. Seasonally poor water quality from upstream metals and nutrients sources.
14	Blackfoot River near mouth	T13N R17W Sec 09 BDD	119.5	1617	Major tributary to the Clark Fork and a control station above Milltown Reservoir
15	Clark Fork below Milltown Dam	T13N R18W Sec 18 CBC	122.0	3012	Milltown Reservoir has trapped large quantities of metals orginating upstream in the Clark Fork drainage and is a designated Superfund site. This station allows comparison of metals and other pollutants from above to below reservoir.
16	Clark Fork above Missoula WWTP	T13N R19W Sec 18 DDA	129.4	---	Control station above City of Missoula wastewater discharge. Continuing seasonal metals and other water quality problems.

Table 1. Continued.

Station Number	Station Name	Legal Description	River Mile[1]	Average Annual Flow (cfs)[2]	Station Rationale
17	Missoula WWTP discharge	T13N R19W Sec 18 DDA	129.5	10.2[3]	Large volume point-source municipal discharge to Clark Fork.
18	Clark Fork at Shuffield's	T13N R20W Sec 24 AAD	131.5	---	Station allows examination of effects of Missoula wastewater discharge on Clark Fork water quality. Control station above the Bitterroot River.
19	Bitterroot River near mouth	T13N R20W Sec 26 CBD	134.5	2466 (Est.)	Major tributary to the Clark Fork.
20	Clark Fork at Harper Bridge	T14N R21W Sec 35 ADA	142.0	5478	Control station above Stone Container Corporation Missoula Mill. Test station below the Bitterroot River.
21	Stone Container Corporation Missoula Mill wastewater discharge				
	Discharge 001	T14N R21W Sec 23 DBB	144.5	9.0[4] (average combined flow)	
	Discharge 003	T14N R21W Sec 14 BBC	145.5		Large volume point-source industrial discharge to Clark Fork.
22	Clark Fork at Huson	T15N R22W Sec 26 ACB	154.0	---	Station allows examination of effects of Stone wastewater on Clark Fork water quality.
23	Clark Fork near Alberton	T14N R23W Sec 12 AAB	164.5	---	Stations 23 and 24 allow examination of the effects of the Missoula WWTP and Stone discharges and other pollutants (e.g. metals) with increasing distance from their sources.
24	Clark Fork at Superior	T17N R26W Sec 34 ABB	202.5	---	
25	Clark Fork above Flathead River	T19N R25W Sec 33 DAD	242.0	7508	Control station above the Flathead River.

Table 1. Continued.

Station Number	Station Name	Legal Description	River Mile[1]	Average Annual Flow (cfs)[2]	Station Rationale
26	Flathead River near mouth	T18N R24W Sec 05 DDC	242.5	12352 (Est.)	The largest tributary to the Clark Fork. On the average, more than doubles the volume of flow.
27	Clark Fork above Thompson Falls Reservoir	T21N R27W Sec 33 BCB	266.5	19860	Station allows examination of Flathead River influence on Clark Fork water quality and serves as a control station above Thompson Falls Reservoir.
28	Clark Fork below Thompson Falls Dam	T22N R30W Sec 36 BDC	286.5	20569 (Est.)	Station allows comparison of water quality from above to below Thompson Falls reservoir and also serves as a control station above Noxon Rapids Reservoir.
29	Clark Fork below Noxon Rapids Dam	T26N R32W Sec 19 DAB	323.5	20760	Station allows comparison of water quality from above to below Noxon Rapids Reservoir and serves as a control station above Cabinet Gorge Reservoir.
30	Clark Fork Below Cabinet Gorge Dam	T27N R3E Sec 20 DCC	345.5	22260	Station allows comparison of water quality from above to below Cabinet Gorge Reservoir and characterizes water quality of Clark Fork as it leaves Montana and enters Lake Pend Oreille, Idaho.

1 River mileages from headwaters computed from Montana Department of Natural Resources and Conservation, 1984.

2 Average annual streamflows from U.S. Geological Survey, 1988, except where otherwise indicated.

3 Average flow rates for the Butte and Missoula WWTP's are averages for the period July 1987 - June 1988.

4 Average flow rates for the Stone Container Corporation wastewater discharge are averages for the period July 1987-June 1989.

Table 2. Monitoring Activities, Frequency and Water Quality Variables[1]

A. Chemical and Physical Water Quality Monitoring

The following parameters were measured monthly during low streamflow conditions and two to three times monthly during spring runoff at each of 32 locations:

- o Streamflow
- o Water temperature
- o pH and alkalinity
- o Water hardness
- o Metals (total recoverable copper, zinc, arsenic (FY88) or copper, zinc, cadmium and lead (FY89).
- o Nutrients[1] (orthophosphate, total phosphorus, nitrate plus nitrite nitrogen, ammonia nitrogen, total Kjeldahl nitrogen)
- o Total and volatile suspended sediment

B. Biological Water Quality Monitoring

The following biological samples were collected once each summer (August) at each of 25 locations:[2]

- o Four quantitative macroinvertebrate samples
- o One periphyton qualitative composite sample

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1 Beginning in October 1987, all analyses for orthophosphate, nitrate plus nitrite and ammonia were performed on filtered samples giving results as dissolved fractions, except for the Stone Container Corporation wastewater which was unfilterable.

2 Evaluations of the biological water quality monitoring data are given in separate reports (Bahls, 1989; McGuire, 1989a, 1989b).

Table 3. Stations at Which each Monitoring Activity was Performed

Station		Metals	Nutrients	Suspended Sediment	Macroinvertebrates	Periphyton
00	Silver Bow Creek above Butte Metro wastewater treatment plant (WWTP)[1]	X	X	X	X	X
00.5	Butte Metro WWTP discharge	X	X	X		
01	Silver Bow Creek below Colorado Tailings	X	X	X	X	X
02	Silver Bow Creek at Miles Crossing near Ramsay	X	X	X	X	X
03	Silver Bow Creek above AMC Warm Springs Ponds	X	X	X	X	X
04	Discharge from AMC Warm Springs Pond #2	X	X	X	X	X
05	Mill-Willow Creek Bypass at mouth	X	X	X	X	X
06	Warm Springs Creek at mouth	X	X	X	X	X
07	Clark Fork below Warm Springs Creek	X	X	X	X	X
08	Clark Fork near Deapsey	X	X	X	X	X
09	Clark Fork at Deer Lodge	X	X	X	X	X
10	Clark Fork above Little Blackfoot River	X	X	X	X	X
11	Clark Fork at Gold Creek Bridge	X	X	X	X	X
12	Clark Fork at Bonita	X	X	X	X	X
13	Clark Fork at Turah	X	X	X	X	X
14	Blackfoot River near mouth	X	X	X	X	X
15	Clark Fork below Milltown Dam	X	X	X	X	X
16	Clark Fork above Missoula WWTP	X	X	X	X	X
17	Missoula WWTP discharge	X	X	X		
18	Clark Fork at Shuffield's	X	X	X	X	X
19	Bitterroot River near mouth	X	X	X	X	X
20	Clark Fork at Harper Bridge	X	X	X	X	X
21	Stone Container Corporation wastewater discharge	X	X	X		
22	Clark Fork at Huson	X	X	X	X	X
23	Clark Fork near Alberton	X	X	X	X	X
24	Clark Fork at Superior	X	X	X	X	X
25	Clark Fork above Flathead River	X	X	X	X	X
26	Flathead River near mouth	X	X	X		
27	Clark Fork above Thompson Falls Reservoir	X	X	X	X	X
28	Clark Fork below Thompson Falls Dam	X	X	X		
29	Clark Fork below Noxon Rapids Dam	X	X	X		
30	Clark Fork below Cabinet Gorge Dam	X	X	X		

1 Station 00 first established in September 1987.

2. METHODS

2.1 Field Sampling and Streamflow

Water samples for analysis of metals, nutrients and common ions were grab-sampled in new and/or acid-washed polyethylene bottles at mid-depth in the main current of the river. Effluents were sampled at their points of discharge to the receiving stream. Beginning in October 1987, samples for dissolved nutrient analysis were collected in acid-washed bottles and field-filtered through a glass fiber prefilter and a 0.45 µm membrane filter. Samples for suspended sediment analysis were collected in glass bottles with a DH-48 suspended sediment sampler using the equal-width-increment method (USGS, 1985) to the limit of wadeability. Water temperatures were measured with a mercury field thermometer having graduations of 1°C and a resolution of 0.1°C. Measurements of pH were made in the field with a portable field pH meter at monitoring stations 00-10. Water samples for pH measurement were collected at the remaining stations and transported on ice to Helena for laboratory measurement. Samples were stored on ice and hand-carried or bussed to the laboratory. All sample collection, handling, preservation and storage procedures followed EPA-approved methods described in MDHES, 1989.

Discharge rates for effluents were measured at the time of sample collection with the primary flow measuring device located at each outfall (weir, flume, or totalizer). Mainstem and tributary streamflows were gaged with a Marsh-McBirney Model 2100 water current meter at the time of sample collection, or were obtained from the U.S. Geological Survey where gaging stations corresponded to our monitoring sites. Streamflows for the Clark Fork below Thompson Fall Dam were obtained from the Montana Power Company. Relevant field observations were routinely recorded at all monitoring locations.

Sample collection methods and the sources of streamflow data for each monitoring station are summarized in Tables 4 and 5.

2.2 Chemical Analysis

All samples were analyzed by the Montana Department of Health (MDHES) Chemistry Laboratory Bureau within approved holding times. Parameters analyzed on all samples included total recoverable metals (copper, zinc, arsenic in FY 1988; copper, zinc, cadmium, lead in FY 1989), nutrients (total phosphorus, orthophosphate, total Kjeldahl nitrogen, nitrate plus nitrite nitrogen and ammonia nitrogen), suspended sediment (total and volatile), selected common ions (calcium and magnesium for water hardness determination) and alkalinity and pH. Beginning in October 1987, all analyses for orthophosphate, nitrate plus

Table 4. Sample Collection and Analysis Methods

Variable	Collection Method	Analytical Method	Laboratory
A. Chemical/Physical Water Quality Monitoring			
Streamflow (cfs)	-----	Instream field determination[1,2]	Field personnel
Water Temperature (°C)	-----	Instream field determination[1]	Field personnel
pH (standard pH units)	Grab sample	EPA 150.1[3]	Field personnel or MDHES chemistry lab
Alkalinity (mg/l as $CaCO_3$)	Grab sample	EPA 310.2[3]	MDHES chemistry lab
Hardness (mg/l as $CaCo_3$)	Grab sample	EPA 200.7[3]	MDHES chemistry lab
Total Recoverable Metals (ug/l)[4]	Grab sample		MDHES chemistry lab
Copper (TR Cu)		EPA 200.7, 220.1, 220.2[3]	
Zinc (TR Zn)		EPA 200.7, 289.1, 289.2[3]	
Arsenic (TR As)		EPA 200.7, 206.2, 206.3[3]	
Cadmium (TR Cd)		EPA 200.7, 213.1, 213.2[3]	
Lead (TR Pb)		EPA 200.7, 239.1, 239.2[3]	
Algal Nutrients (ug/l)[5]	Grab sample Dissolved nutrients field-filtered (0.45um) prior to analysis.		MDHES chemistry lab
Orthophosphate (Ortho P)		EPA 365.1[3]	
Total Phosphorus (Total P)		EPA 365.1[3]	
Nitrate + Nitrite (NO_3+NO_2 as N)		EPA 353.2[3]	
Total Ammonia (Total NH_3+NH_4 as N)		EPA 350.1[3]	
Total Kjeldahl (Total KJL-N as N)		EPA 351.2[3]	
Suspended Sediment (mg/l)	Effluents grab sampled. Streams depth-integrated from shore to limit of wadeability. EWI method[6]		MDHES chemistry lab
Total (TSS)		EPA 106.2[3]	
Volatile (VSS)		EPA 160.4[3]	

Continued . . .

Table 4. Continued.

Variable	Collection Method	Analytical Method	Laboratory
B. Biological Water Quality Monitoring			
Benthic Macroinvertebrate Community Structure Parameters	Modified Hess sampler[6]	Species identifications and counts made using numerous current taxonomic references.	Daniel L. McGuire (contractor)
Periphyton Community Structure Parameters	Composite sampling technique[6]	Species identifications and counts made using numerous current taxonomic references.	MDHES WQB (Loren L. Bahls)

1 Field procedures for streamflow and water temperature measurements are given in Montana Department of Health and Environmental Sciences, 1989.

2 Streamflows for monitoring stations 00, 02-08 and 10 were gaged. Wastewater flows for stations 00.5, 17 and 21 were obtained at the time of sample collection from permanent flowmeters. Streamflows for the remaining stations are from U.S. Geological Survey gaging station records.

3 Analytical methods are from U.S. Environmental Protection Agency, 1983 (Revised).

4 Total recoverable copper, zinc and arsenic were analyzed in FY 1988 by ICP and AA methods. Total recoverable copper, zinc, cadmium and lead were analyzed in FY 1989 by carbon furnace or ICP methods.

5 Analyses for orthophosphate, nitrate plus nitrite and ammonia are as total concentrations for the period July through September 1987. Analyses for the period October 1987 through June 1989 were performed on filtered samples and results are as dissolved concentrations, except for the Stone Container Corporation wastewater which was unfilterable.

6 Biological monitoring methods and results are presented in separate reports (Bahls, 1989; McGuire, 1989a, 1989b).

Table 5. Sources of Streamflow Data

Station Number	Source of Streamflow Data for Individual Sampling Dates[1]	Remarks	Source of Monthly Average Streamflow Data	Remarks
00	Streamflow generally gaged during each visit.	Reported as instantaneous streamflow.	Gaged flows averaged for month.	Monthly average streamflows should be considered rough estimates only.
00.5	Wastewater flow measured with weir located onsite.	Reported as instantaneous streamflow.	Mean monthly flows obtained from Butte WWTP records.	Monthly average streamflows accurate.
01	Streamflow obtained from USGS records for gaging station Silver Bow Creek below Blacktail Creek.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
02_2	Streamflow generally gaged during each visit.	Reported as instantaneous streamflow.	Gaged flows averaged for month.	Monthly average streamflows should be considered rough estimates only.
03	Streamflow generally gaged during each visit.	Reported as instantaneous streamflow.	Gaged flows averaged for month.	Monthly average streamflows should be considered rough estimates only.
04	Streamflow generally gaged during each visit.	Reported as instantaneous streamflow.	Gaged flows averaged for month.	Monthly average streamflows should be considered rough estimates only.
05	Streamflow generally gaged during each visit.	Reported as instantaneous streamflow.	Gaged flows averaged for month.	Monthly average streamflows should be considered rough estimates only.
06	Streamflow generally gaged during each visit. Ungageable flows obtained from USGS records for gaging station Warm Springs Creek at Warm Springs.	Reported as instantaneous streamflow. Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
07	Streamflow generally gaged during each visit.	Reported as instantaneous streamflow.	Gaged flows averaged for month.	Monthly average streamflows should be considered rough estimates only.

Table 5. Continued.

Station Number	Source of Streamflow Data for Individual Sampling Dates[1]	Remarks	Source of Monthly Average Streamflow Data	Remarks
08	Streamflow generally gaged during each visit.	Reported as instantaneous streamflow.	Gaged flows averaged for month.	Monthly average streamflows should be considered rough estimates only.
09	Streamflow obtained from USGS records for gaging station Clark Fork at Deer Lodge.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
10	Streamflow generally gaged during each visit.	Reported as instantaneous streamflow.	Gaged flows averaged for month.	Monthly average streamflows should be considered rough estimates only.
11	Streamflow obtained from USGS records for gaging station Clark Fork at Gold Creek.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
12	Streamflow obtained from USGS records for gaging station Clark Fork near Clinton.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
13	Streamflow obtained from USGS records for gaging station Clark Fork at Turah.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
14	Streamflow obtained from USGS records for gaging station Blackfoot River near Bonner.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
15	Streamflow obtained from USGS records for gaging station Clark Fork above Missoula.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.

Table 5. Continued.

Station Number	Source of Streamflow Data for Individual Sampling Dates[1]	Remarks	Source of Monthly Average Streamflow Data	Remarks
16	Streamflow obtained from USGS records for gaging station Clark Fork above Missoula.	Reported as estimated mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows fair estimates.
17	Wastewater flow measured with permanent flowmeter located onsite.	Reported as instantaneous streamflow.	Mean monthly flows obtained from Missoula WWTP records.	Monthly average streamflows accurate.
18	Streamflow obtained from USGS records for gaging station Clark Fork above Missoula.	Reported as estimated mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows fair estimates.
19	Streamflow estimated by subtracting flow for USGS gaging station Clark Fork above Missoula from flow for USGS gaging station Clark Fork below Missoula.	Reported as estimated mean daily streamflow.	Mean monthly flows estimated by subtracting USGS mean monthly flow for Clark Fork above Missoula from USGS mean monthly flow for Clark Fork below Missoula.	Monthly average streamflows should be considered rough estimates only.
20	Streamflow obtained from USGS records for gaging station Clark Fork below Missoula.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
21	Wastewater flow measured with permanent flowmeter located onsite.	Reported as instantaneous flow.	Mean monthly flows obtained from Stone Container Corporation Missoula Mill records.	Monthly average streamflows accurate.
22	Streamflow obtained from USGS records for gaging station Clark Fork below Missoula.	Reported as estimated mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows good estimates.
23	Streamflow obtained from USGS records for gaging station Clark Fork below Missoula.	Reported as estimated mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows fair estimates.

Table 5. Continued.

Station Number	Source of Streamflow Data for Individual Sampling Dates[1]	Remarks	Source of Monthly Average Streamflow Data	Remarks
24	Streamflow data not available.	----------	Streamflow data not available.	----------
25	Streamflow obtained from USGS records for gaging station Clark Fork at St. Regis.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
26	Streamflow obtained from USGS records for gaging station Flathead River at Perma.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
27	Streamflow obtained from USGS records for gaging station Clark Fork near Plains.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
28	Streamflow computed by adding flow for USGS gaging station Prospect Creek at Thompson Falls to flow at Thompson Falls Dam recorded by the Montana Power Company (MPC).	Reported as mean daily streamflow.	Mean monthly flows computed by adding USGS mean monthly flow for Prospect Creek to MPC mean monthly flow at Thompson Falls Dam.	Monthly average streamflows accurate.
29	Streamflow obtained from USGS records for gaging station Clark Fork below Noxon Rapids Dam.	Reported as mean daily streamflow.	USGS mean monthly flows obtained for gaging station.	Monthly average streamflows accurate.
30	Streamflow obtained from USGS records for gaging station Clark Fork at Whitehorse Rapids.	Reported as mean daily streamflow.	USGS mean monthly flow obtained for gaging station.	Monthly average streamflows accurate.

1 Streamflows for stations 02, 03, 07 and 10 occasionally were estimated due to ungageable conditions (ice or high water) and are reported as such. Streamflows for USGS gaging stations occasionally were reported as estimates due to ice effects.

2 Streamflows measurements during FY 1988 did not include a side channel. Flow data for FY 1988 can be considered underestimates.

nitrite and ammonia were performed on filtered samples giving results as dissolved fractions, except for the Stone Container Corporation wastewater which was unfilterable. Also note that metals detection limits were lowered in FY 1989 due to the availability of new lab instrumentation.

Analytical methods are summarized in Table 4.

2.3 Water Quality Analysis

Upon receipt of the analytical reports from the laboratory, all data were hand-tabulated and visually inspected for possible errors. All data for the two-year monitoring period were then entered onto a computer spreadsheet and reviewed for transcription errors. The computer program was designed to:

1. catalogue the chemical and physical data by station, parameter group and year

2. compute statistical summaries and calculate total discharges (or loads) of pollutants by station, parameter group and year

3. calculate criteria values for the protection of aquatic life for those parameters not having fixed criteria (e.g. metals, ammonia)

4. compare parameter concentration data to water quality criteria and determine the annual frequency and average magnitude of exceedence of the criteria by station, parameter and year

5. evaluate the relative severity of the problem for individual parameters (e.g. copper) and for groups of parameters (e.g. metals) at each station by assigning severity scores.

This information provided the basis for the water quality assessments in this report. The system relies on several basic assumptions which must be explained because of their potential influence on the water quality assessments:

1. From one to three sampling events took place during any given month of the two year period (except February 1989 when no sampling was conducted). Monthly average concentrations were computed from these individual data and annual average concentrations were computed from the monthly averages. In order for the computed averages to be representative, individual sampling events would have had to take place during conditions which were representative of the time interval (month, half month, etc.). Every effort was made to insure

that this was the case. For example, streamflows were monitored by telephone on a regular basis and compared to a hydrograph in order to time sampling events. However, river conditions may change quickly and without warning as a function of the weather. On several occasions, monitoring frequency may have been inadequate or timing of monitoring may have been poor and prevailing pollutant concentrations may not be accurately reflected in the data. As a result, an unknown degree of error in the representativeness of the data is inherent in the program.

2. At various times during the monitoring period, pollutant concentrations were measured at less than their respective analytical detection limits. In the computation of average concentrations and total annual discharges (loads), it was necessary to assign a value to those measurements reported as not detectable. Four options were available: 1) assume that the measurement was at the detection limit, 2) assume the value was zero, 3) assign an arbitrary value based on a statistical analysis or a "best guess", or 4) use the midpoint between the detection limit and zero. Each option has its problems. While the second option may in some cases underestimate average pollutant concentrations and loads, it seemed to be the most practical approach. Only at the lower-most Clark Fork monitoring stations and in some tributaries were pollutant concentrations frequently below detection. Data were not available to use option three or to determine the suitability of option four.

3. Water quality criteria for the protection of freshwater aquatic life were the primary basis for the water quality evaluations in this report. For these evaluations to be representative of the suitability of water quality in the Clark Fork Basin for the designated beneficial water uses associated with I, C-1, C-2 and B-1 water quality classes, these criteria must be at least as low as the criteria for any of the intended uses. In other words, the assumption used is that if water quality is adequate to protect aquatic life, other beneficial uses will not be precluded. With one exception, this assumption holds true. The arsenic criterion for the protection of freshwater aquatic life is 190 ug/l (U.S.EPA, 1986) while the maximum contaminant level for drinking water is 50 ug/l (A.R.M, 1982). The B-1 class, which applies to the Clark Fork below the Little Blackfoot River, states

that water quality shall be maintained for drinking purposes. As a result, arsenic data were manually reviewed for exceedences of the drinking water standard.

4. Chronic toxicity aquatic life criteria for metals and ammonia are expressed in terms of a four-day average concentration that should not be exceeded more than once every three years. Acute toxicity criteria are given in terms of a one-hour average concentration that should not be exceeded more than once every three years. The evaluation of the frequency of at which these criteria were exceeded instream and the assigning of pollution severity scores for each monitoring station were based on instantaneous measurements. Continuous monitoring would have been necessary to confirm that the exceedences which were documented were in fact sustained for four consecutive days (in the case of the chronic criterion) or for one hour (acute criterion). Of course this would be impractical. For the purpose of these reports, an instantaneously documented exceedence of a criterion value was considered to be an exceedence of the four-day or one-hour criterion. While this is a reasonable approach for metals, it may present a problem for ammonia toxicity evaluations. This is because pH and water temperature, which are highly variable on a daily (or diel) basis, strongly influence the toxicity of ammonia. Consequently, the criterion value at a given station can be expected to swing widely on a 24-hour basis, while the concentration of total ammonia measured instream would be expected to remain relatively stable. For these reasons, some caution is necessary in the review of the ammonia toxicity evaluations.

5. A final assumption relates to the metals analysis method which was employed. As previously indicated, water samples were analyzed for total recoverable metals. Because comparisons are made to the EPA metals criteria, it is important to note that the total recoverable method used by the MDHES Chemistry Laboratory differs from the EPA total recoverable method, which the criteria are expressed in terms of. The EPA total recoverable method employs a soft digestion of the sample prior to sample analysis. This process releases a certain quantity of sediment-bound metals that may be present in some samples. The MDHES method consists of field acidification (preservation) of the samples but lacks the digestion step. The MDHES method has been shown to produce comparable results and it is compatible with nearly all available

data concerning toxicity and bioaccumulation of metals by aquatic organisms. The EPA criteria are based on a total recoverable method utilizing a digestion step because it is possible for sediment-bound metals in a wastewater discharge to eventually become bioavailable in a receiving stream as the chemical and physical properties of the wastewater change upon mixing. The MDHES total recoverable method is suitable for surface waters but could underestimate the toxicity potential of metals present in wastewaters.

Given these assumptions, a description follows as to how frequency and magnitude of criteria exceedences were computed and how the severity analysis scheme works.

Frequency of exceedence of the relevant water quality criteria for metals, nutrients and ammonia are computed on the basis of the instantaneous measurement data for each station. For example, one exceedence of a criterion in a month where two measurements were made would result in a computed frequency of exceedence of the criterion of 50 percent for that month. These values are averaged for the twelve month monitoring period to give the annual average frequency of exceedence of the criterion.

The magnitude of the criteria exceedence is computed by comparing the monthly average concentrations to the criteria and averaging these ratios (or percentages of the criteria) for the twelve month period. Simply put, a magnitude of exceedence of two indicates that the average monthly value for a parameter at a given station was twice the criterion. While not necessarily significant from the standpoint of aquatic toxicity from metals or ammonia (i.e. does it really matter by how much the threshold concentration is exceeded when it is exceeded?), the magnitude of exceedence value indicates the relative severity of the problem for the parameter in question at a given station. It also provides a gage as to how much concentrations would have to be reduced, on the average, to prevent criteria exceedences. These data are not specifically evaluated in this report but are included in the appendices and are used to compute the severity scores, described below.

Pollution severity scores for metals, nutrients and ammonia were assigned to each monitoring station by multiplying the frequency of exceedence for a given parameter by the magnitude of exceedence. For example, if the concentration of a pollutant like copper was exactly at the criterion 100 percent of the time it was measured, the computed copper severity score would be one. It is possible that infrequent, but large-scale exceedences of a criterion at a station would yield a comparable severity score to a station that experienced more frequent, but smaller scale exceedences. Consequently, the severity scoring system is not capable of delineating between chronic or acute

problems nor can it necessarily be related directly to actual toxicity problems -- it is relative, not quantitative. However the system does provide a quick reference to the relative severity of ambient concentrations throughout the Clark Fork Basin.

Suspended sediment data are treated differently than metals, nutrients or ammonia. This is necessary because the suspended sediment criteria used are given in terms of concentration ranges which provide a given level of protection to aquatic communities. Suspended sediment data are evaluated on the basis of the frequency of distribution of the monthly average concentrations among four levels of protection for freshwater aquatic life: high level (<25 mg/l), moderate level (25-80 mg/l) low level (80-400 mg/l), and very low level of protection (>400 mg/l). The magnitude value for suspended sediment (equivalent to the magnitude of the criteria exceedence, as used for the other parameters) is computed using the highest level of protection category (<25 mg/l) as a basis, with the premise being that 200 mg/l of suspended sediment is four times as bad as 25 mg/l, from the standpoint of aquatic life protection. For example, if several measurements fell in the moderate level of protection category and averaged 50 mg/l, the magnitude score for that category would be two. The suspended sediment severity score for a station is computed by summing the products of the frequency and magnitude scores for each of the four levels of protection categories (e.g. high level frequency X high level magnitude + moderate level frequency X moderate level magnitude, and so on). The suspended sediment severity score theoretically would be one if the suspended sediment concentration was at the upper end of the high level of protection category each time a measurement was made. Scores of one or less indicate infrequent and/or slight excursions from the high level of protection suspended sediment concentration range.

2.4 Quality Assurance

A number of procedures were followed in the laboratory and in the field to insure the integrity of data. All apparatus used in collecting and filtering samples for dissolved nutrients was cleaned thoroughly before each reuse. Collection bottles, sample bottles, filter holders, and syringes were soaked for a minimum of several hours in a solution of 25 percent HCl to remove trace concentrations of nitrogen and phosphorous. All apparatus was then rinsed thoroughly with distilled/deionized water.

Bottles for collecting samples for analysis of total phosphorous and total Kjeldahl nitrogen were rinsed three times with ambient water, as were collection bottles for dissolved nutrients. Filters were purged once with a 50 ml aliquot of sample, then again with another 50 ml aliquot which was used to

rinse sample bottles. Two filter blanks were collected during each sampling episode by collecting, filtering and preserving a quantity of distilled/deionized water following the procedures used for ambient samples. This documented the thoroughness of cleaning techniques and the amount of contamination introduced by sample handling and preservation.

Sample bottles for metals analyses were soaked with a solution of 5% nitric acid for several days to remove any trace concentrations of metals. Immediately before sample collection, bottles were then rinsed three times with ambient water. Preservatives were stored in reusable teflon ampules to further minimize the possibility of contamination. A field blank was also collected during each sampling episode to document the thoroughness of cleaning techniques and the amount of contamination introduced by sample handling and preservation.

Once a quarter, field-originated duplicate and spiked samples were submitted to the laboratory to validate that the accuracy and precision limits of laboratory data were not violated by the combined effects of field sampling procedures and laboratory analytical methods.

The laboratory maintains a strict quality assurance/quality control program which ensures that all generated data were of known quality (precision and accuracy). This program involves the extensive use of duplicates, spikes, known standards, and EPA audit samples. (MDHES, 1974). Laboratory quality assurance limits and detection limits are summarized in MDHES, 1987.

3. RESULTS

3.1 Streamflows

Mean streamflows at mainstem monitoring stations during FY 1988 are presented in Figure 2. Mean streamflows in tributaries and wastewater discharges during FY 1988 appear in Figures 3 and 4. Figures 5-7 are hydrographs for the Clark Fork at Deer Lodge (upper river), below Missoula (middle river) and Plains (lower river), showing FY 1988 streamflows together with record high, record low and normal streamflows for the available period of U.S. Geological Survey (USGS) records. Also shown are points on each hydrograph during which sampling was conducted. Individual FY 1988 streamflow data and summaries are included in the appendices.

At the time of report preparation, FY 1989 USGS streamflow data were largely unavailable. The available FY 1989 streamflow data appear in the appendices.

FIGURE 2

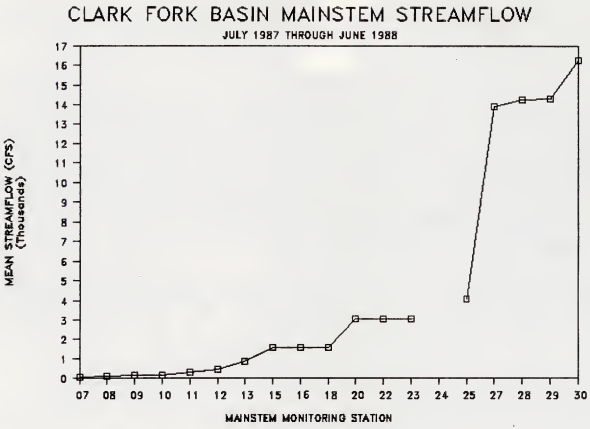


FIGURE 3

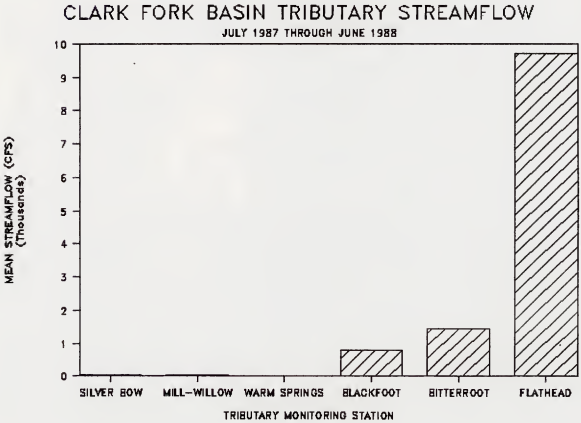


FIGURE 4

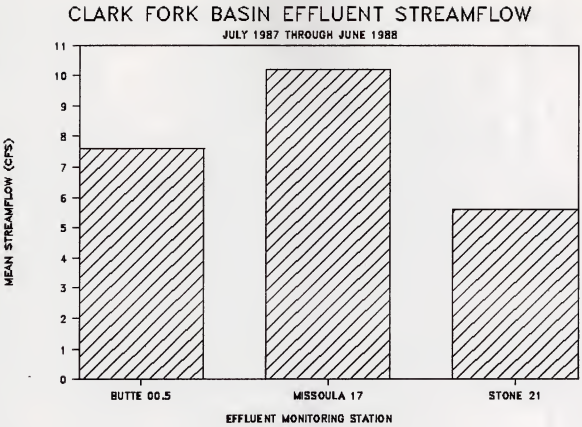

CLARK FORK BASIN EFFLUENT STREAMFLOW
JULY 1987 THROUGH JUNE 1988
MEAN STREAMFLOW (CFS)
0
1
2
3
4
5
6
7
8
9
10
11
BUTTE 00.5
MISSOULA 17
STONE 21
EFFLUENT MONITORING STATION

FIGURE 5

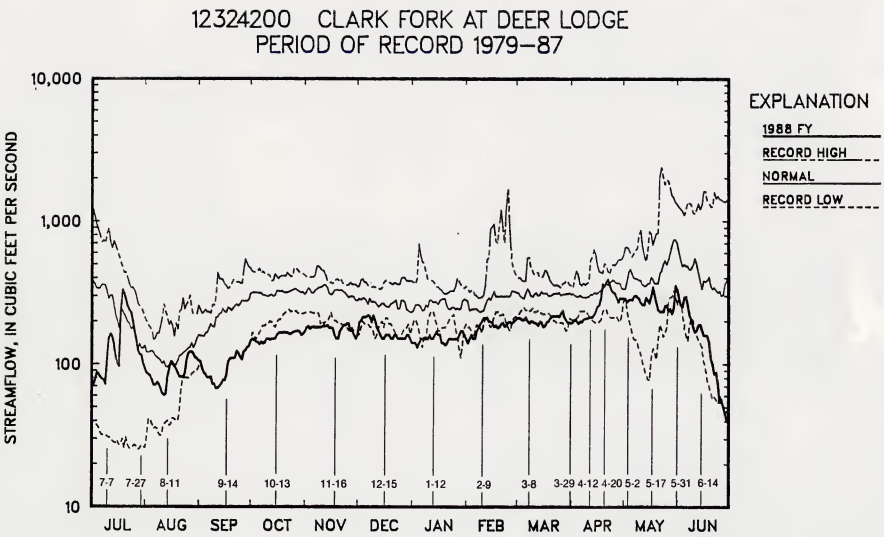

12324200 CLARK FORK AT DEER LODGE
PERIOD OF RECORD 1979–87
STREAMFLOW, IN CUBIC FEET PER SECOND
10,000
1,000
100
10
7-7
7-27
8-11
9-14
10-13
11-16
12-15
1-12
2-9
3-8
3-29
4-12
4-20
5-2
5-17
5-31
6-14
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
EXPLANATION
1988 FY
RECORD HIGH
NORMAL
RECORD LOW

FIGURE 6

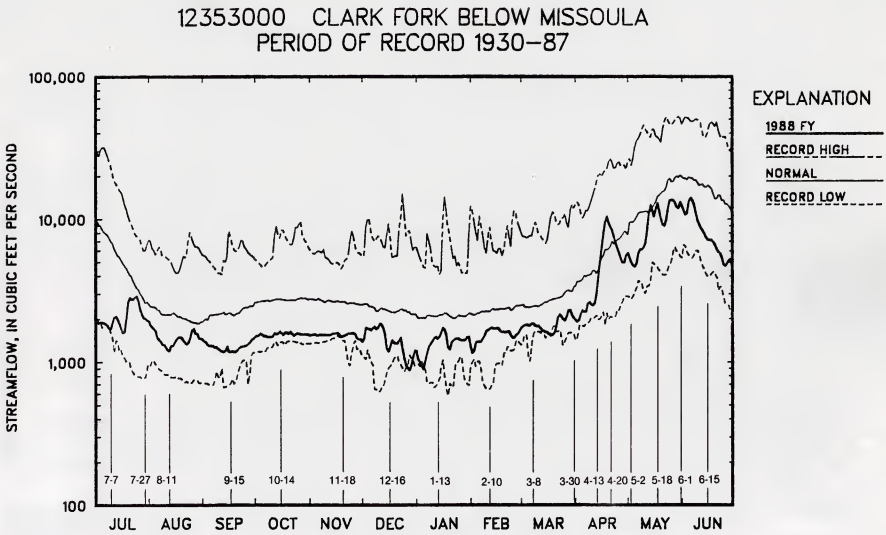
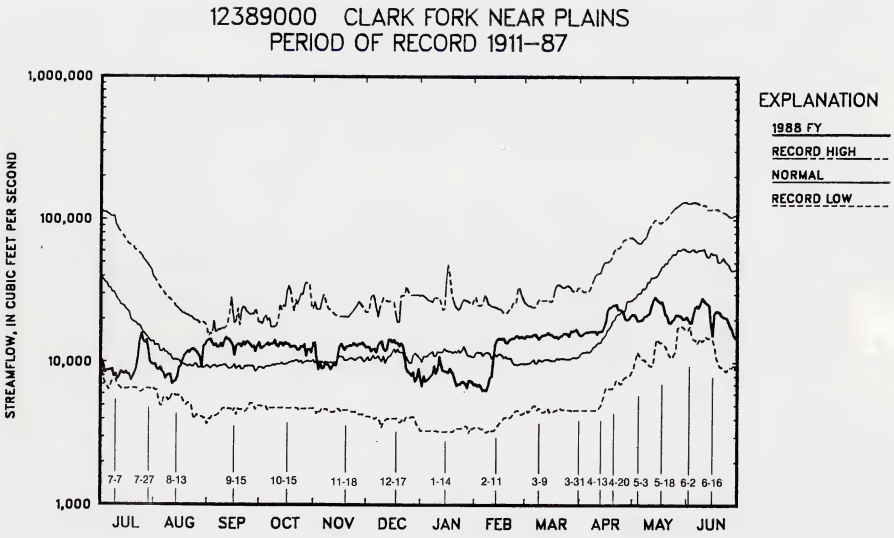

12353000 CLARK FORK BELOW MISSOULA
PERIOD OF RECORD 1930–87
STREAMFLOW, IN CUBIC FEET PER SECOND
100,000
10,000
1,000
100
7-7
7-27
8-11
9-15
10-14
11-18
12-16
1-13
2-10
3-8
3-30
4-13
4-20
5-2
5-18
6-1
6-15
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
EXPLANATION
1988 FY
RECORD HIGH
NORMAL
RECORD LOW

FIGURE 7


12389000 CLARK FORK NEAR PLAINS
PERIOD OF RECORD 1911–87
STREAMFLOW, IN CUBIC FEET PER SECOND
1,000,000
100,000
10,000
1,000
7-7
7-27
8-13
9-15
10-15
11-18
12-17
1-14
2-11
3-9
3-31
4-13
4-20
5-3
5-18
6-2
6-16
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
EXPLANATION
1988 FY
RECORD HIGH
NORMAL
RECORD LOW

3.2 Metals

Concentration ranges and mean values for total recoverable copper, zinc and arsenic at each monitoring station during FY 1988 are presented in Table 6. Concentration ranges and means for total recoverable copper, zinc, cadmium and lead in FY 1989 are given in Table 7.

Graphs of maximum, minimum and mean metals concentrations and mean chronic toxicity criteria values for freshwater aquatic life (U.S. EPA, 1986) appear in Figures 8-14 (Silver Bow Creek), 15-21 (Clark Fork mainstem) and 22-28 (Clark Fork tributaries). Frequencies at which the EPA chronic toxicity criteria were exceeded at mainstem monitoring stations are graphically presented in Figures 29-35.

Estimated total annual discharges (loads) of copper and zinc in Silver Bow Creek and the Clark Fork River during FY 1988 are shown in Figures 36-37.

Metals pollution severity scores for Clark Fork mainstem monitoring stations are depicted in Figures 38, 39 and 88.

All of the individual metals monitoring data are included in Appendices A and B.

Table 6. Fiscal Year 1988 Clark Fork Basin Total Recoverable Metals Concentration Data Summary

Station Number	N=[1]	Measured Concentration (µg/l) July 1987 through June 1988 TR Copper (TR Cu) Conc. Range	Mean	TR Zinc (TR Zn) Conc. Range	Mean	TR Arsenic (TR As) Conc. Range	Mean
I. Mainstem Stations							
07	17	10- 50	19	16- 97	47	8-36	13
08	17	<10- 80	19	8-106	35	9-26	14
09	17	<10- 50	22	11- 73	38	8-22	13
10	17	10- 80	26	10-118	40	9-23	14
11	17	<10- 50	17	9-112	33	6-18	11
12	17	<10- 60	12	<5-118	29	7-17	10
13	17	<10- 30	<10	<5- 63	18	4- 9	6
15	17	*	<10	<5- 17	7	2- 6	4
16	17	<10- 20	<10	<5- 29	10	1- 6	4
18	17	*	<10	<5- 25	9	1- 6	3
20	17	*	<10	<5- 12	<5	<1- 3	2
22	17	*	<10	<5- 13	<5	<1- 3	2
23	17	*	<10	<5- 14	<5	<1- 3	2
24	17	*	<10	<5- 7	<5	<1- 3	2
25	17	*	<10	<5- 10	<5	<1- 3	2
27	17	*	<10	<5- 17	<5	<1- 1	<1
28	17	*	<10	<5- 5	<5	<1- 1	<1
29	17	*	<10	<5- 9	<5	<1- 1	<1
30	17	*	<10	<5- 8	<5	<1- 1	<1
II. Tributary Stations							
00	17	150-390	238	390- 937	694	7-17	10
01	17	170-410	241	636-1420	896	8-20	11
02	17	130-780	228	522-2150	771	10-33	15
03	17	110-530	190	342-1190	604	12-41	17
04	17	<10- 30	13	7- 156	58	6-13	9
05	17	20- 80	29	20- 90	50	10-75	21
06	17	<10-100	<10	<5- 41	<5	3-18	8
14	17	*	<10	*	<5	<1- 1	<1
19	17	*	<10	<5- 9	<5	*	<1
26	17	*	<10	<5- 6	<5	*	<1
III. Effluent Stations							
00.5	14	<10- 70	14	43-1270	188	2- 5	3
17	17	<10- 30	<10	29- 65	49	<1- 2	1
21	7	*	<10	8- 31	23	3-15	6

1 Copper analyses were limited to 16 measurements at stations 10-20 and 22-30 and 6 measurements at station 21.

* Indicates all measurements were less than the analytical detection limit.

Table 7. Fiscal Year 1989 Clark Fork Basin Total Recoverable Metals Concentration Data Summary

Station Number	N=[1]	Measured Concentration (µg/l) July 1988 through June 1989 TR Copper (TR Cu) Conc. Range	Mean	TR Zinc (TR Zn) Conc. Range	Mean	TR Cadmium (TR Cd) Conc. Range	Mean	TR Lead (TR Pb) Conc. Range	Mean
I. Mainstem Stations									
07	15	9-120	24	12-354	69	<0.2-1.2	0.3	<1- 34	4
08	15	7- 80	22	8.0-216	47	<0.2-1.0	0.3	<1- 22	3
09	15	8- 80	30	9.2-168	54	<0.2-0.5	0.3	<1- 18	4
10	15	8- 80	31	10-148	47	<0.2-0.5	0.2	<1- 16	4
11	15	5- 60	20	7.8-102	32	<0.2-0.4	<0.2	<1- 11	3
12	15	4- 20	9	8.0- 94	28	<0.2-0.3	<0.2	<1- 12	2
13	15	<1- 39	8	5.5- 57	20	<0.2-1.2	<0.2	<1- 7	1
15	15	1- 16	5	4.4- 24	13	<0.2-0.4	<0.2	<1- 2	<1
16	15	1- 14	5	4.4- 53	16	<0.2-1.1	<0.2	<1- 2	<1
18	15	<1- 20	6	2.6- 71	17	<0.2-1.4	<0.2	<1- 4	1
20	15	<1- 9	2	1.9- 23	9	<0.2-0.3	<0.2	<1- 2	<1
22	15	<1- 7	3	1.9- 35	10	*	<0.2	<1- 2	<1
23	15	<1- 7	2	1.8- 23	8	*	<0.2	<1- 1	<1
24	15	<1- 7	2	1.0- 47	10	*	<0.2	<1- 2	<1
25	15	<1- 6	1	1.0- 19	4	<0.2-0.2	<0.2	<1- 2	<1
27	15	<1- 4	<1	<0.5- 39	4	<0.2-0.8	<0.2	<1- 2	<1
28	15	<1- 3	<1	<0.5- 14	3	<0.2-0.2	<0.2	<1- 1	<1
29	15	<1- 13	1	<0.5- 41	7	*	<0.2	<1- 1	<1
30	15	<1- 2	<1	<0.5- 12	3	*	<0.2	<1- 1	<1
II. Tributary Stations									
00	15	160-360	266	526- 973	774	1.5-2.8	2.2	1- 12	3
01	15	170-390	264	830-2250	1143	2.5-4.0	3.1	2- 51	17
02	15	160-440	231	510-1340	846	1.8-5.4	2.9	5- 62	14
03	15	100-620	228	278-1170	710	1.1-5.0	2.6	6-108	19
04	15	3-210	33	5.9- 576	107	<0.2-2.2	0.5	<1- 55	7
05	15	7- 80	27	16- 177	56	<0.2-0.8	0.3	<1- 6	1
06	15	2- 10	6	0.9- 14	5	<0.2-0.2	<0.2	<1- 2	<1
14	15	<1- 2	<1	<0.5- 73	10	<0.2-1.1	<0.2	*	<1
19	14	<1- 5	<1	<0.5- 12	3	*	<0.2	*	<1
26	15	<1- 2	<1	<0.5- 7	2	*	<0.2	<1- 2	<1
III. Effluent Stations									
00.5	15	7- 70	23	24-3880	452	<0.2-0.4	<0.2	<1- 3	1
17	15	4- 19	10	23- 58	42	<0.2-0.2	<0.2	<1- 3	1
21	10	<1- 2	<1	4.2- 24	10	<0.2-0.3	<0.2	<1- 1	<1

1 Cadmium analyses were limited to 12 measurements at stations 00-18 and 20-30 and 11 measurements at station 19.

* Indicates all measurements were less than the analytical detection limit.

FIGURE 8

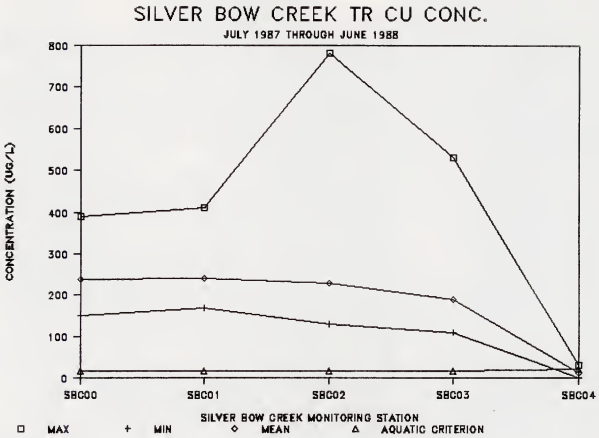


FIGURE 9

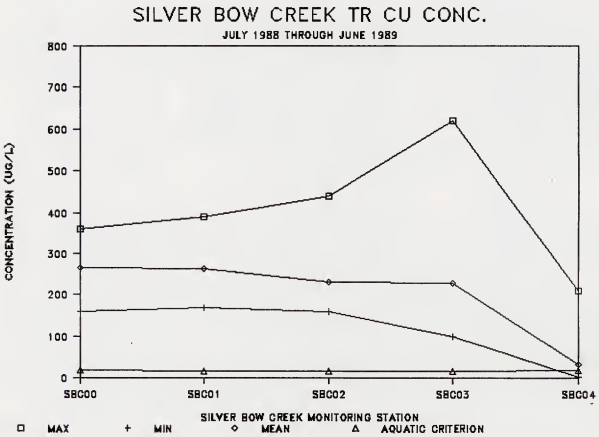


FIGURE 10

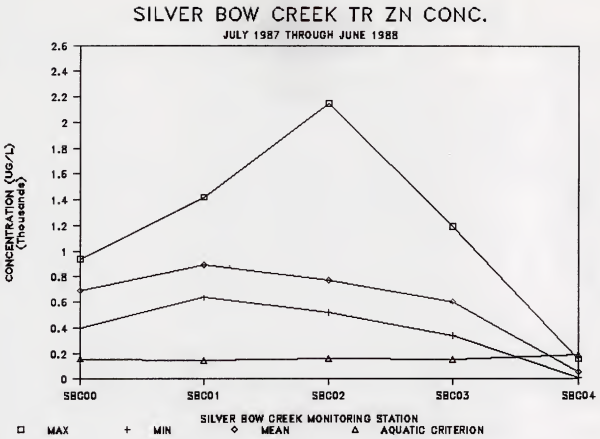


FIGURE 11

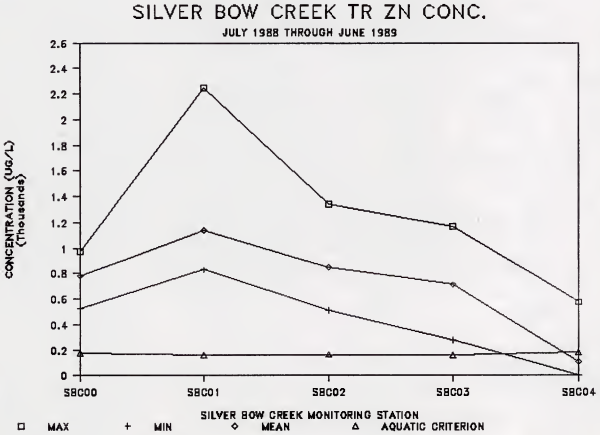


FIGURE 12

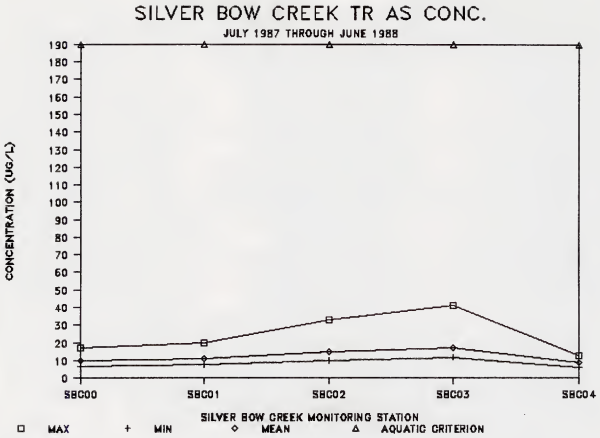

SILVER BOW CREEK TR AS CONC.
JULY 1987 THROUGH JUNE 1988
CONCENTRATION (UG/L)
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
SBC00
SBC01
SBC02
SBC03
SBC04
SILVER BOW CREEK MONITORING STATION
MAX
MIN
MEAN
AQUATIC CRITERION

FIGURE 13

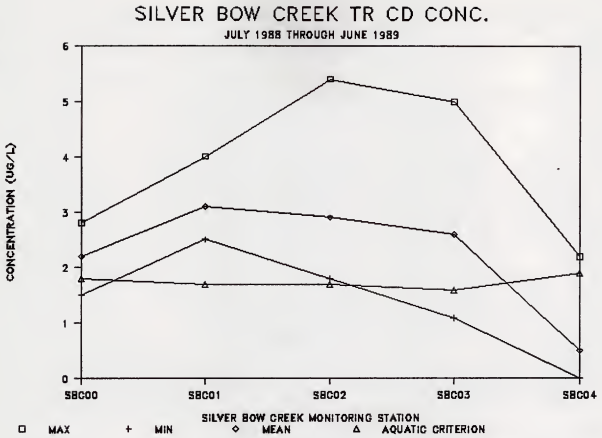


FIGURE 14

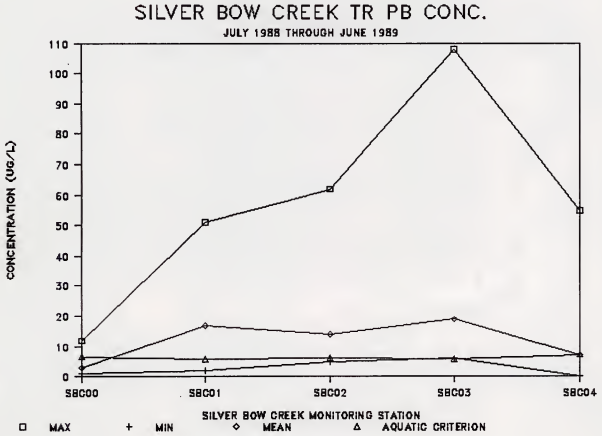


FIGURE 15

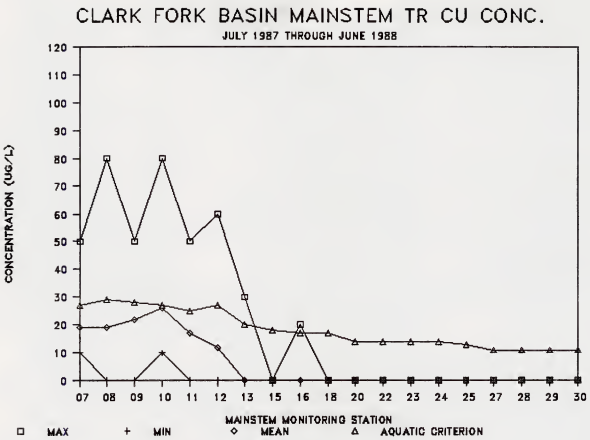


FIGURE 16

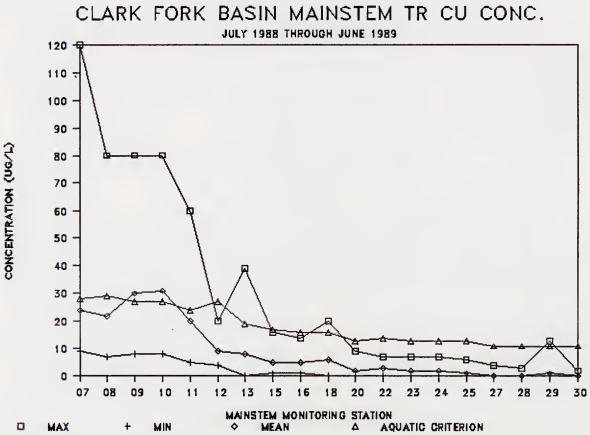


FIGURE 17

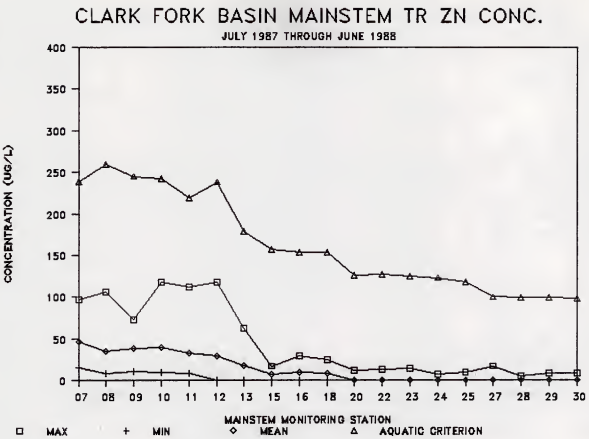


FIGURE 18

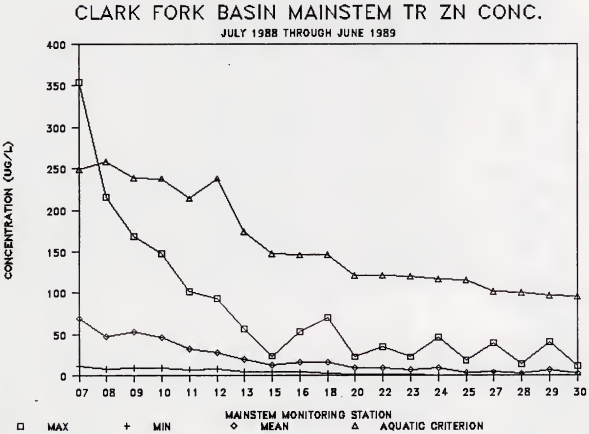


FIGURE 19

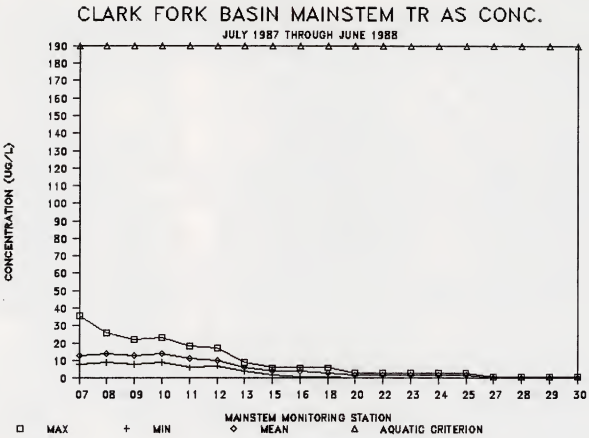

CLARK FORK BASIN MAINSTEM TR AS CONC.
JULY 1987 THROUGH JUNE 1988
CONCENTRATION (UG/L)
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
07 08 09 10 11 12 13 15 16 18 20 22 23 24 25 27 28 29 30
MAINSTEM MONITORING STATION
MAX
MIN
MEAN
AQUATIC CRITERION

FIGURE 20

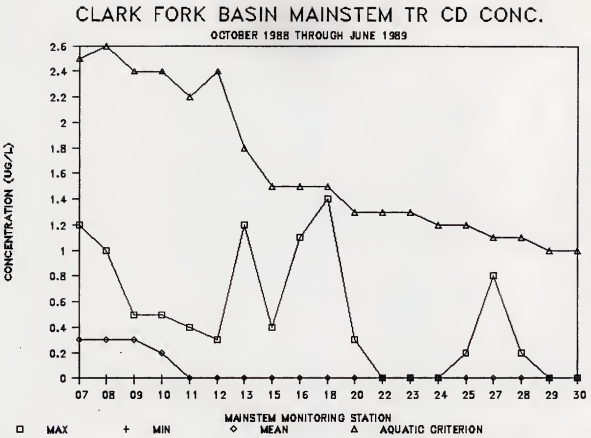


FIGURE 21

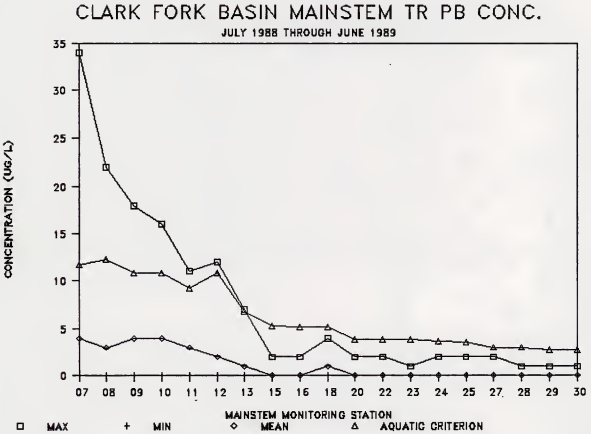


FIGURE 22

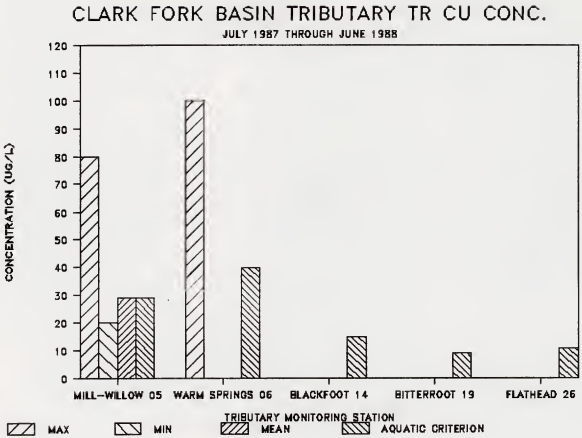


FIGURE 23

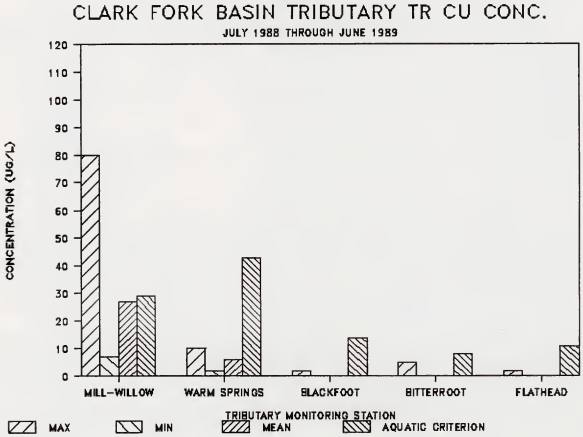


FIGURE 24

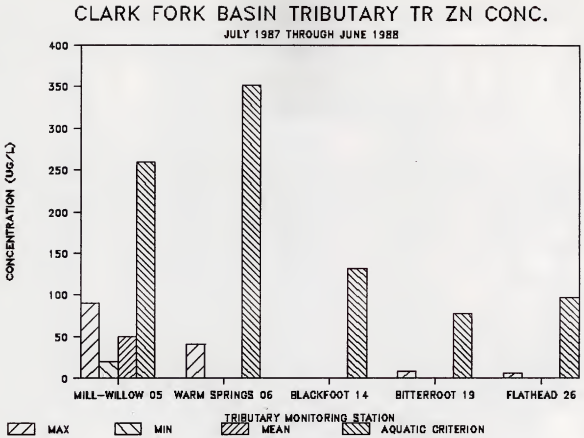


FIGURE 25

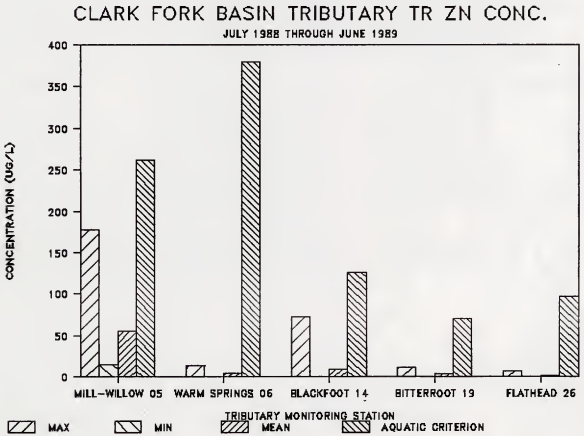


FIGURE 26

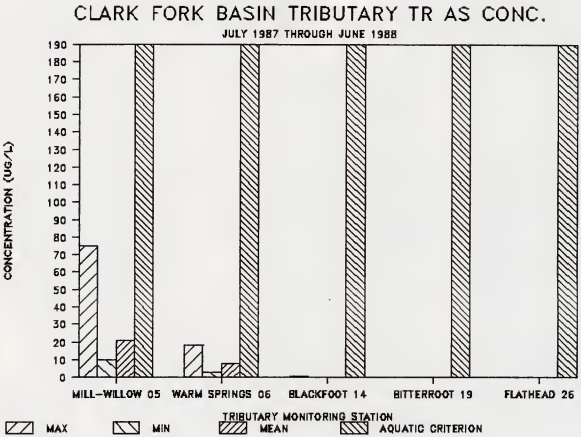

CLARK FORK BASIN TRIBUTARY TR AS CONC.
JULY 1987 THROUGH JUNE 1988
CONCENTRATION (UG/L)
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
MILL-WILLOW 05
WARM SPRINGS 06
BLACKFOOT 14
BITTERROOT 19
FLATHEAD 26
TRIBUTARY MONITORING STATION
MAX
MIN
MEAN
AQUATIC CRITERION

FIGURE 27

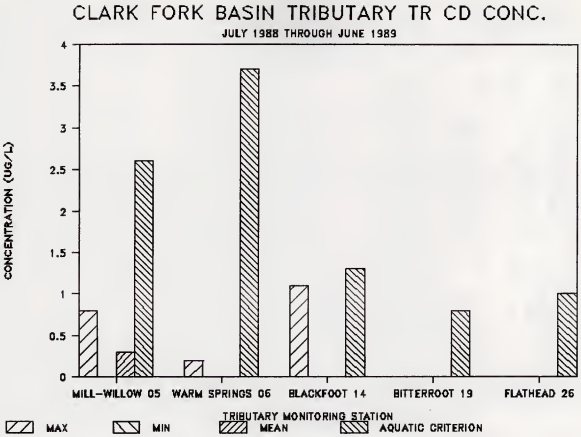


FIGURE 28

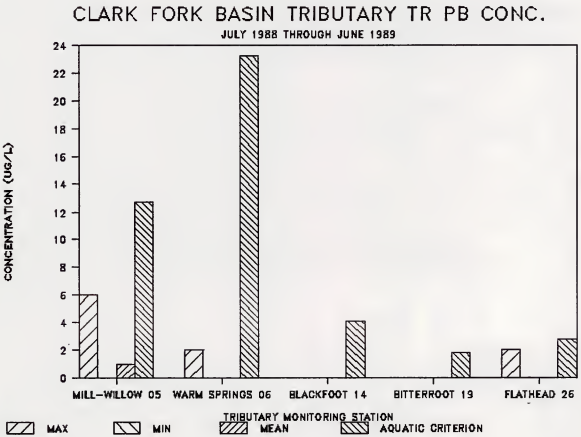


FIGURE 29

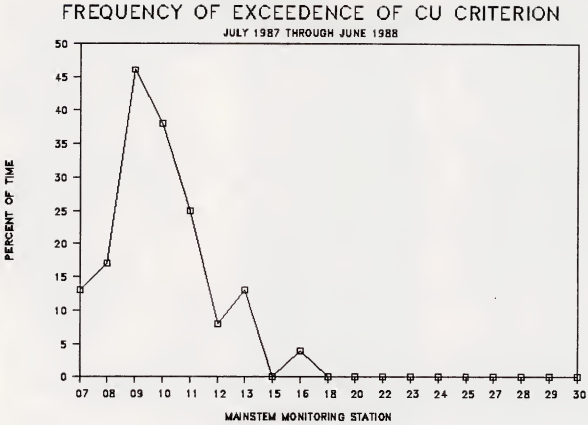


FIGURE 30

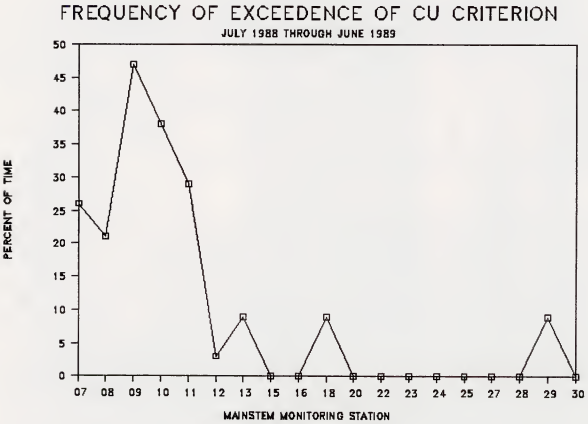


FIGURE 31

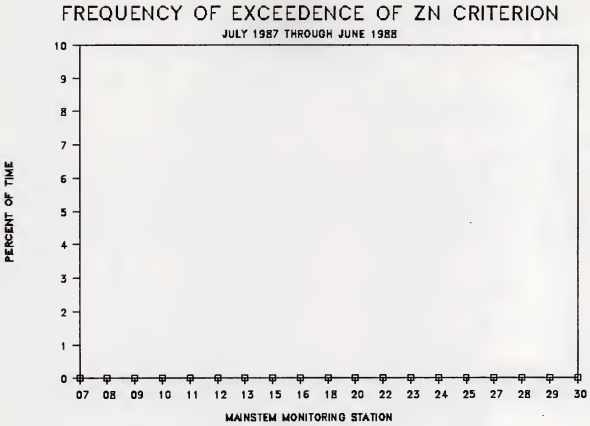


FIGURE 32

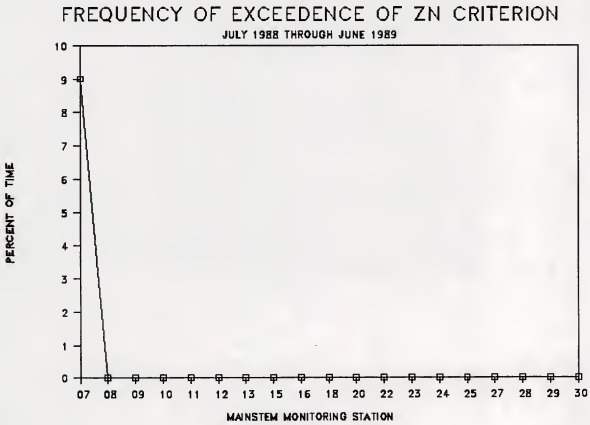


FIGURE 33

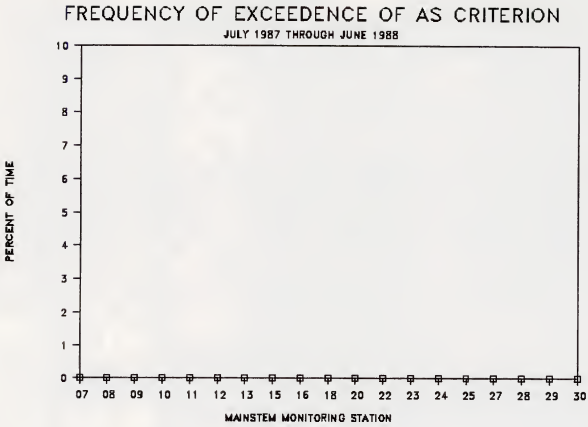

FREQUENCY OF EXCEEDENCE OF AS CRITERION
JULY 1987 THROUGH JUNE 1988
PERCENT OF TIME
10
9
8
7
6
5
4
3
2
1
0
07 08 09 10 11 12 13 15 16 18 20 22 23 24 25 27 28 29 30
MAINSTEM MONITORING STATION

FIGURE 34

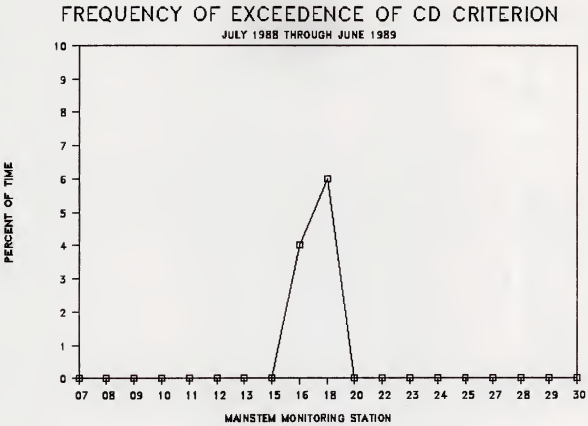


FIGURE 35

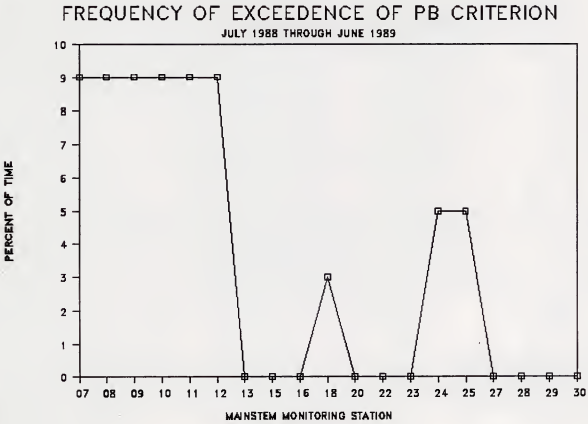


FIGURE 36

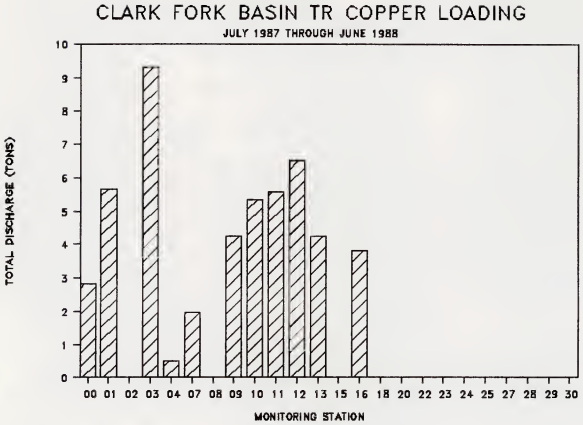


FIGURE 37

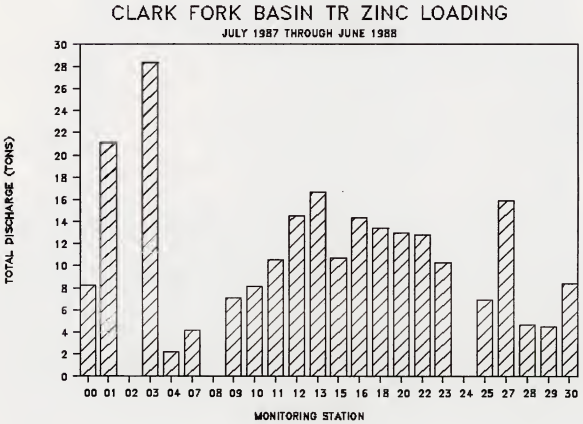


FIGURE 38

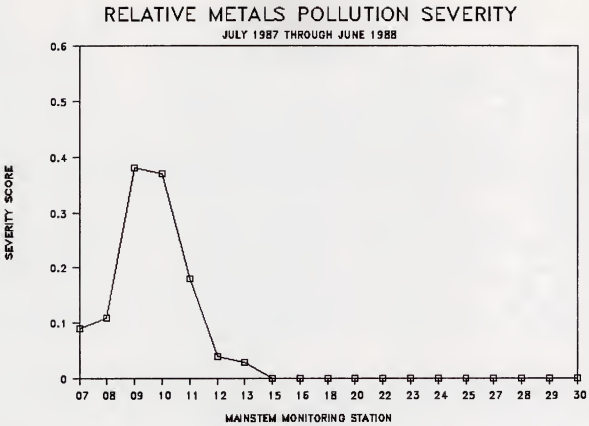
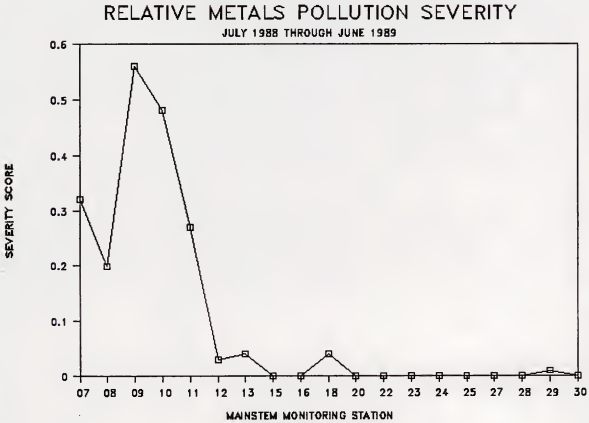


FIGURE 39



3.3 Nutrients

Concentration ranges and mean values for total phosphorus, orthophosphate, total nitrogen and total inorganic nitrogen during FY 1988-1989 are listed in Tables 8 and 9. Note that the data reflect measurements of dissolved orthophosphate (or soluble reactive phosphorus [SRP]) and total soluble inorganic nitrogen (TSIN) for most of the two year monitoring period. However; the first three measurements during FY 1988 were for total concentrations (unfiltered samples) of those parameters.

Graphs of maximum, minimum and mean phosphorus and nitrogen concentrations and EPA nutrient criteria values (U.S. EPA, 1986; MDHES, 1986a) for the prevention of biological nuisances and accelerated cultural eutrophication appear in Figures 40-47 (Silver Bow Creek), 48-55 (Clark Fork mainstem), 56-63 (Clark Fork tributaries) and 64-67 (wastewater discharges). Frequencies at which the EPA nutrient criteria were exceeded at mainstem monitoring stations are graphically presented in Figures 68-71.

Estimated total annual discharges or loads of total and soluble phosphorus and nitrogen in Silver Bow Creek and the Clark Fork River during FY 1988 are given in Figures 72-73. Estimated FY 1988 loads of total phosphorus and total nitrogen in the Missoula and Stone Container Corporation wastewater discharges are displayed in Figure 74. A complete year of data was not available for the Butte WWTP and nutrient loads could not be computed for that station.

Nutrient pollution severity scores for Clark Fork mainstem monitoring stations are given in Figures 75, 76 and 89.

Individual nutrient analysis results for FY 1988-1989 appear in Appendices C and D.

Table 8. Fiscal Year 1988 Clark Fork Basin Nutrient Concentration Data Summary

		Measured Concentration (µg/l) July 1987 through June 1988							
Station Number	N=[1]	Total Phosphorus Conc. Range	Mean	Diss. O-PO_4 (SRP)[2] Conc. Range	Mean	Total Nitrogen[3] Conc. Range	Mean	Diss. Inorganic Nitrogen (TSIN)[4] Conc. Range	Mean
I. Mainstem Stations									
07	17	36-130	86	1-86	24	200- 940	562	20-660	176
08	17	28-131	64	2-33	13	200-1000	582	<10-660	207
09	17	19-144	57	<1-28	8	300-1110	678	50-660	273
10	17	49-196	87	12-64	32	300-1550	698	<10-730	255
11	17	42-169	69	3-47	27	200- 960	588	<10-550	200
12	17	19-220	60	4-54	17	200-1000	477	<10-320	89
13	17	14-114	39	1-27	9	<100- 680	359	<10-240	62
15	17	10- 41	23	<1-21	7	<100- 540	255	<10-120	41
16	17	10- 80	26	<1-16	5	<100- 600	242	<10-160	32
18	17	40- 80	62	14-60	40	214- 700	430	20-290	129
20	17	22- 59	36	6-25	12	140- 590	338	<10-230	94
22	17	22- 69	41	7-34	16	<100- 700	361	10-260	87
23	17	24- 81	37	2-31	13	100- 670	314	<10-220	68
24	17	16- 59	32	<1-23	10	100- 550	283	<10-220	59
25	17	11- 81	29	<1-14	6	<100- 620	279	<10-190	52
27	17	3- 43	14	<1- 9	1	<100- 470	242	<10- 70	20
28	17	2- 34	12	<1- 9	2	<100- 440	206	<10- 70	26
29	17	1- 19	10	<1- 8	1	<100- 410	172	<10- 90	31
30	17	1- 26	10	<1- 5	1	<100- 420	163	<10- 70	25
II. Tributary Stations									
00	17	72- 195	98	10- 104	35	1370-2360	1829	900-2080	1454
01	17	921-1750	1374	500-1470	982	3840-6630	5049	2800-5530	4215
02	17	462-1300	865	53- 720	436	1930-5970	3231	950-4590	2565
03	17	345- 863	567	46- 337	226	1500-3340	2473	840-3400	1862
04	17	81- 269	146	1- 160	44	430-1900	866	<10-1310	296
05	17	22- 96	43	<1- 34	7	310-1150	495	30- 340	153
06	17	1- 165	19	<1- 9	3	100- 850	306	<10- 160	55
14	17	3- 30	12	<1- 5	1	<100- 520	195	<10- 80	27
19	17	7- 60	23	<1- 19	5	120- 740	374	20- 250	111
26	17	2- 46	12	<1- 5	<1	<100- 590	179	<10- 90	25

Table 8. Continued.

Station Number	N=[1]	Measured Concentration (μg/l) July 1987 through June 1988: Total Phosphorus Conc. Range	Mean	Diss. O-PO_4 (SRP)[2] Conc. Range	Mean	Total Nitrogen[3] Conc. Range	Mean	Diss. Inorganic Nitrogen (TSIN)[4] Conc. Range	Mean
III. Effluent Stations									
00.5	14	3590- 4980	4095	2450-4290	3251	8570-13980	11553	7320-11410	9547
17	17	3840-18300	5980	2520-6130	4605	9680-23120	16937	8310-21920	15629
21[5]	17	773- 1090	921	173- 513	312	1800- 7530	4984	290- 1420	992

1 O-PO_4, total nitrogen and TSIN analyses were limited to 16 measurements at stations 00-03, excluding 00.5. Total nitrogen analyses were limited to 16 measurements at stations 11-20 and 22-30.

2 Analysis for dissolved O-PO_4 (0.45μm filtration) was initiated in October 1987 at all sites except station 21. Analyses for the period July - September 1987 were performed on unfiltered samples and results are as total O-PO_4.

3 Total nitrogen was computed by summing measured concentrations of nitrate plus nitrite nitrogen (see 4 below) and total Kjeldahl nitrogen.

4 TSIN was computed by summing measured concentrations of nitrate plus nitrite nitrogen and ammonia nitrogen. Nitrate plus nitrite and ammonia nitrogen concentrations were measured in unfiltered samples from July - September 1987. All analyses were done on filtered samples (0.45μm filter) from October 1987-June 1988, except station 21.

5 Station 21, the Stone Container Corporation wastewater discharge, was consistently unfilterable. All nutrient analyses are as total concentrations.

Table 9. Fiscal Year 1989 Clark Fork Basin Nutrient Concentration Data Summary

		Measured Concentration (µg/l) July 1988 through June 1989							
Station Number	N=[1]	Total Phosphorus Conc. Range	Mean	Diss. O-PO_4 (SRP)[2] Conc. Range	Mean	Total Nitrogen[3] Conc. Range	Mean	Diss. Inorganic Nitrogen (TSIN)[4] Conc. Range	Mean
I. Mainstem Stations									
07	15	21-112	62	<1-70	21	230-1370	688	30-1070	307
08	15	24-135	51	2-18	11	250-1450	653	<10-1150	259
09	15	12-133	51	2-15	7	270-1390	695	40- 940	330
10	15	53-165	91	8-92	36	210-2740	788	<10-2540	348
11	15	38-133	72	10-84	30	220-1170	543	<10- 59	183
12	15	18-180	60	6-53	21	200-1330	520	<10- 750	123
13	15	15-104	36	3-34	12	120-1020	372	10- 460	90
15	15	13- 59	29	3-21	8	100-1130	358	<10- 800	80
16	15	15- 57	29	2-20	8	<100-1130	263	<10- 210	48
18	15	30-106	68	8-96	42	110- 660	399	30- 280	147
20	15	20- 60	41	7-23	14	<100- 550	294	30- 230	103
22	15	23-108	47	8-29	16	100- 440	323	<10- 240	83
23	15	23- 70	40	8-20	14	<100- 580	297	<10- 220	62
24	15	15- 79	31	6-21	9	<100- 320	218	<10- 190	62
25	15	12- 70	25	2-18	7	<100- 510	248	<10- 310	47
27	15	7- 59	18	<1-13	3	<100- 260	108	<10- 110	23
28	15	7- 46	17	<1- 8	2	<100- 240	101	<10- 100	19
29	15	8- 45	16	<1-14	4	<100- 410	196	<10- 180	51
30	15	7- 31	14	<1- 5	3	<100- 490	161	<10- 150	43
II. Tributary Stations									
00	15	58- 129	94	9- 55	19	1320-5600	2239	760-5440	1897
01	15	1040-1890	1440	526-1180	893	3750-6240	5326	2850-5670	4593
02	15	610-1230	836	76- 645	344	2230-5600	3907	1870-5390	3403
03	15	259- 998	523	36- 384	146	1270-3460	2599	820-3230	2031
04	15	40- 320	123	1- 137	40	320-2140	882	<10-1220	360
05	15	19- 69	37	<1- 21	9	230-1050	514	30- 380	181
06	15	8- 28	14	<1- 16	6	<100-1050	330	20- 300	102
14	15	5- 53	20	1- 16	4	<100- 940	234	<10- 440	58
19	15	11- 286	46	2- 8	5	<100-1290	359	40-1090	117
26	15	4- 78	16	<1- 19	3	<100- 220	115	<10- 120	24

Table 9. Continued.

Station Number	N=[1]	Measured Concentration (μg/l) July 1988 through June 1989: Total Phosphorus Conc. Range	Total Phosphorus Mean	Diss. O-PO_4 (SRP)[2] Conc. Range	Diss. O-PO_4 (SRP)[2] Mean	Total Nitrogen[3] Conc. Range	Total Nitrogen[3] Mean	Diss. Inorganic Nitrogen (TSIN)[4] Conc. Range	Diss. Inorganic Nitrogen (TSIN)[4] Mean
III. Effluent Stations									
00.5	15	3190-4470	3667	2200-3990	3099	8680-13960	11763	6810-11970	10117
17	15	3250-6150	4789	2680-5300	4454	11460-41620	17224	10110-22850	15093
21[5]	10	368- 829	567	92-566	287	2400- 8100	4522	790- 1990	1388

1 TSIN analyses were limited to 14 measurements at stations 20 and 22-30 and 9 measurements at station 21.

2 All O-PO_4 analyses are as dissolved concentrations(0.45μm filtration) except station 21.

3 Total nitrogen was computed by summing measured concentrations of dissolved nitrate plus nitrite nitrogen and total Kjeldahl nitrogen.

4 TSIN was computed by summing measured concentrations of dissolved nitrate plus nitrite nitrogen and dissolved ammonia nitrogen.

5 Station 21, the Stone Container Corporation wastewater discharge, was consistently unfilterable. All nutrient analyses are as total concentrations.

FIGURE 40

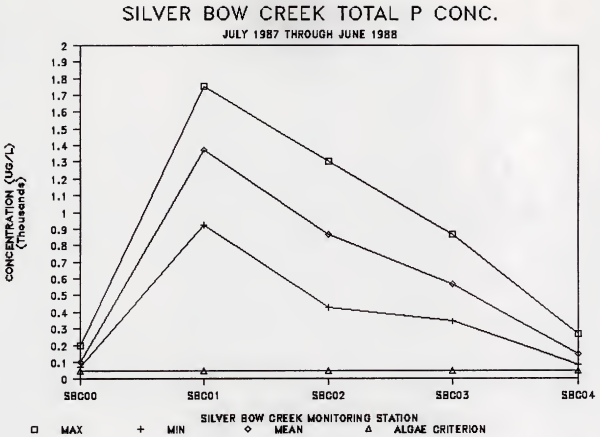


FIGURE 41

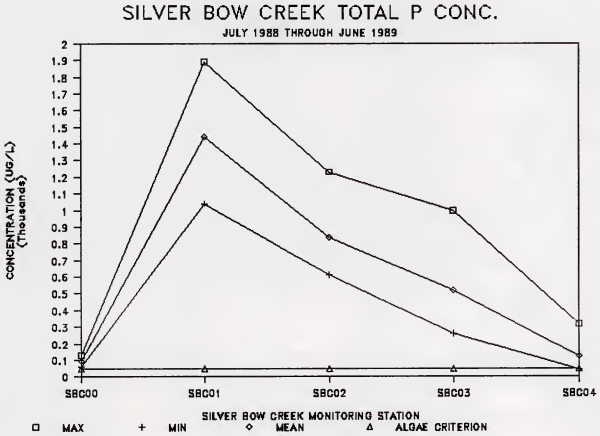


FIGURE 42

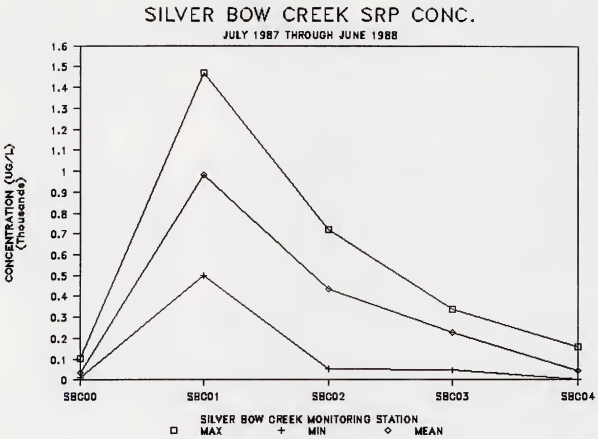


FIGURE 43

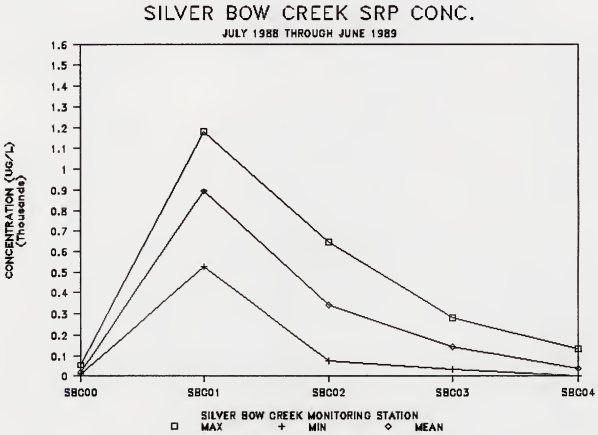


FIGURE 44

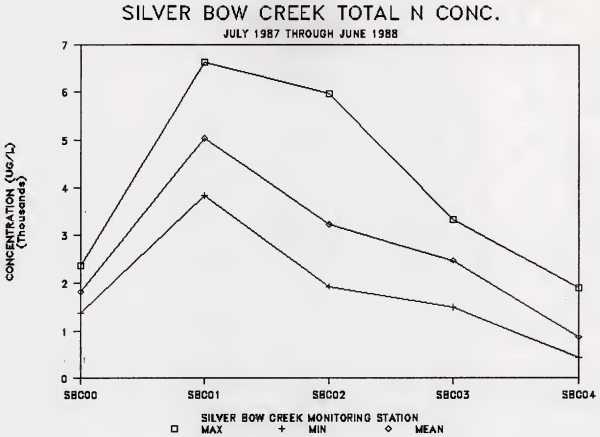


FIGURE 45

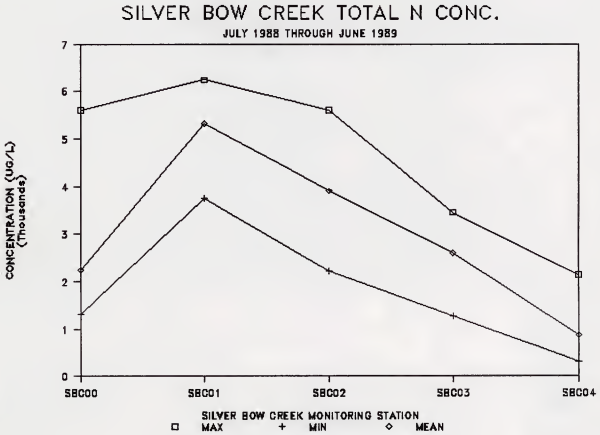


FIGURE 46

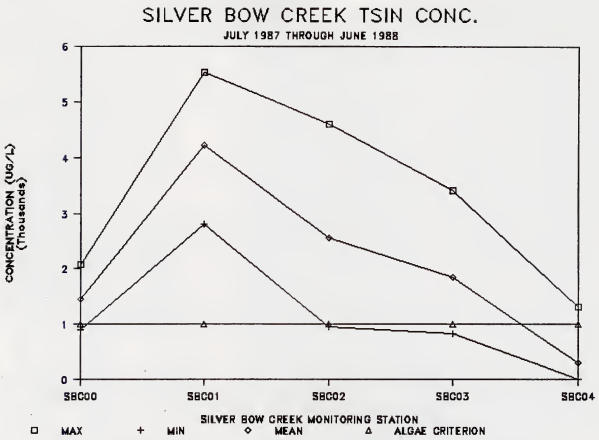


FIGURE 47

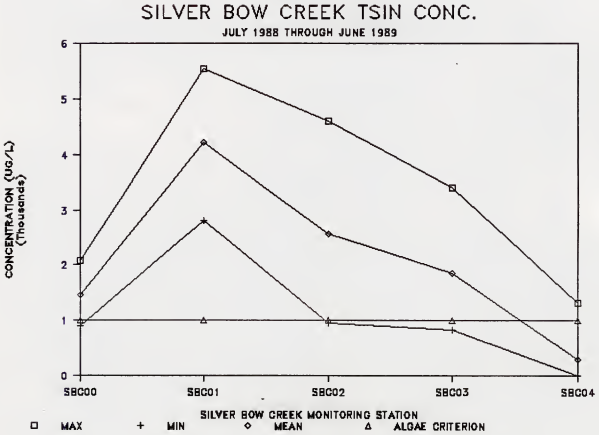


FIGURE 48

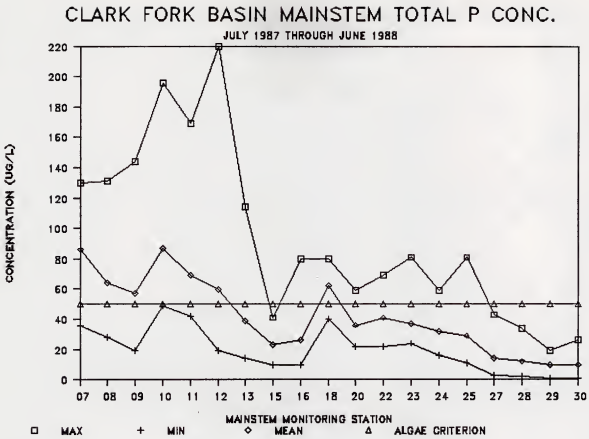


FIGURE 49

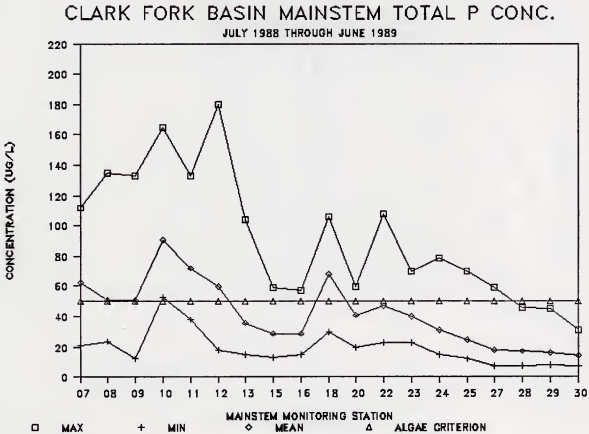


FIGURE 50

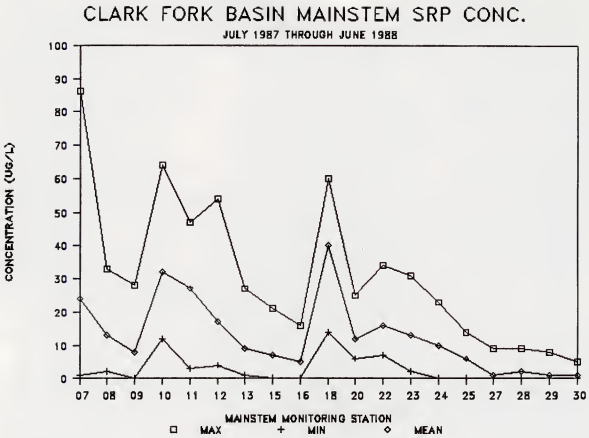


FIGURE 51

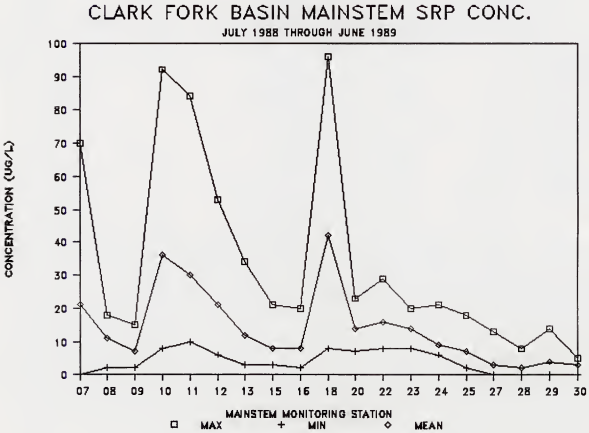


FIGURE 52

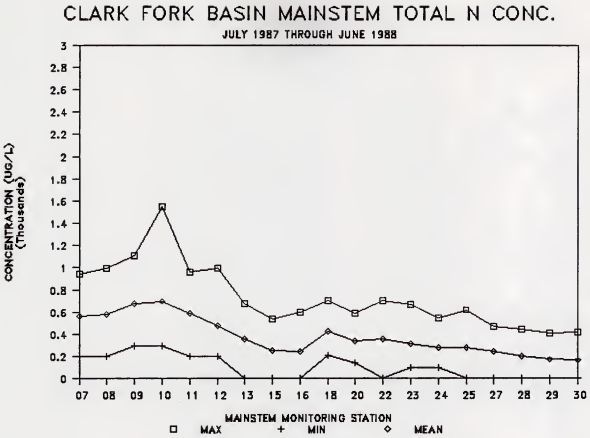


FIGURE 53

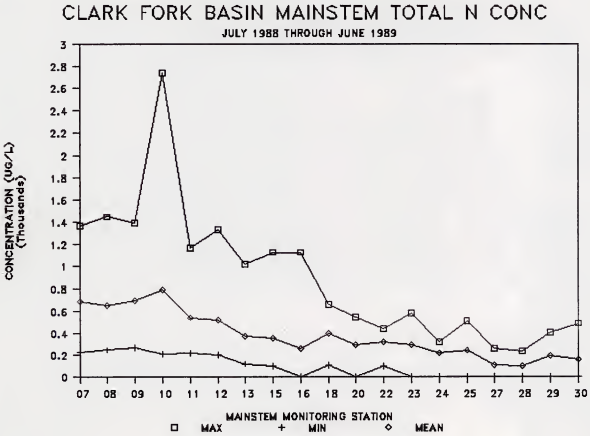


FIGURE 54

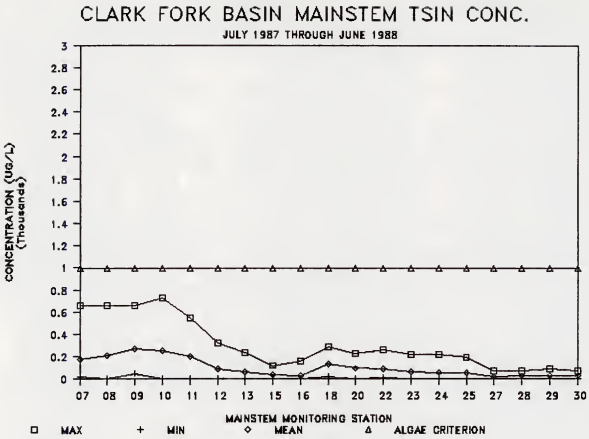


FIGURE 55

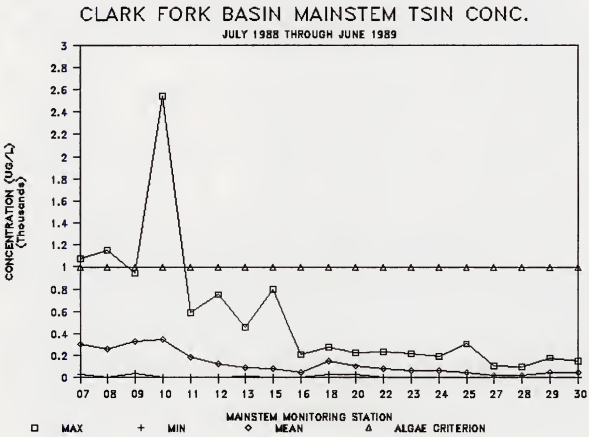


FIGURE 56

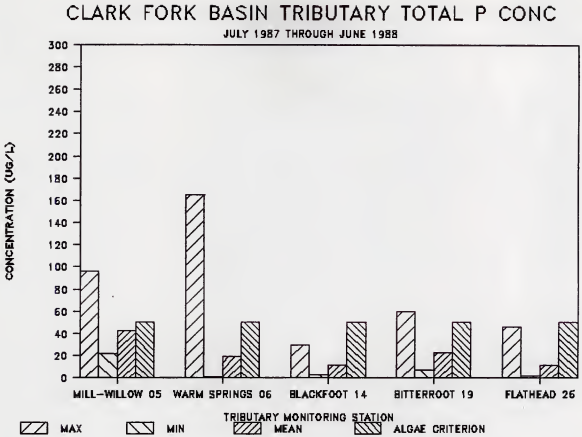
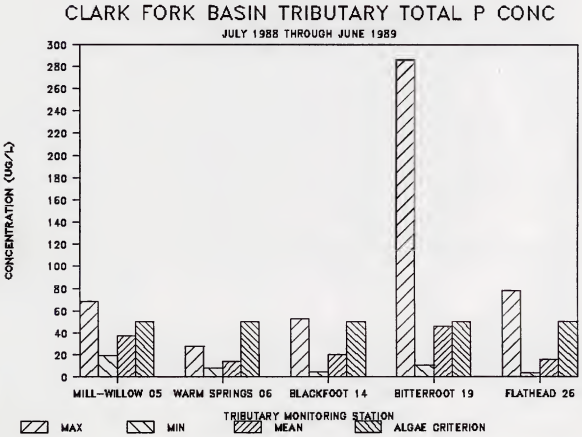


FIGURE 57



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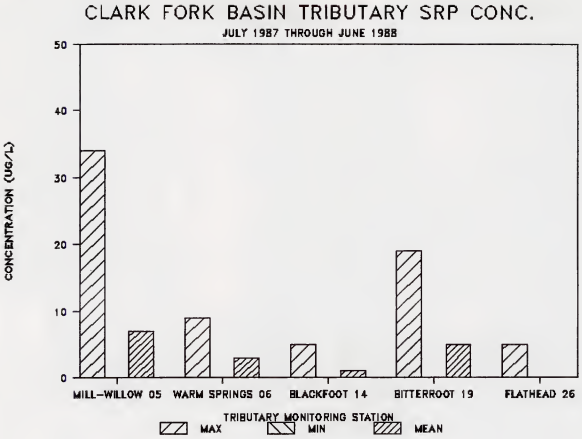


FIGURE 59

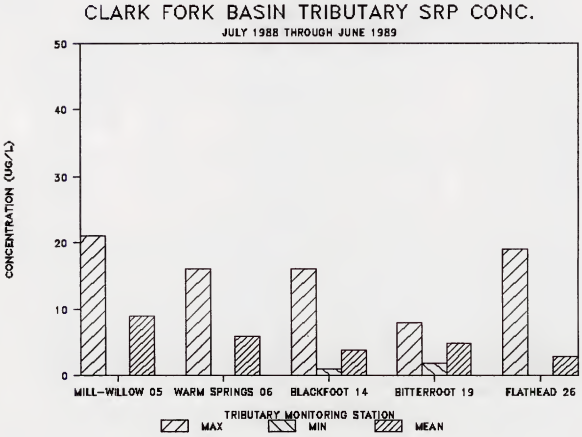


FIGURE 60

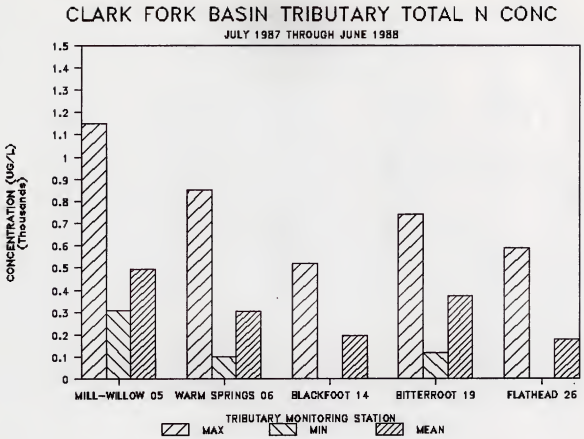


FIGURE 61

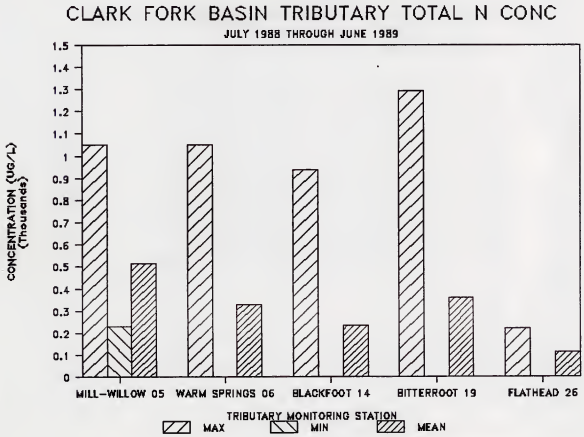


FIGURE 62

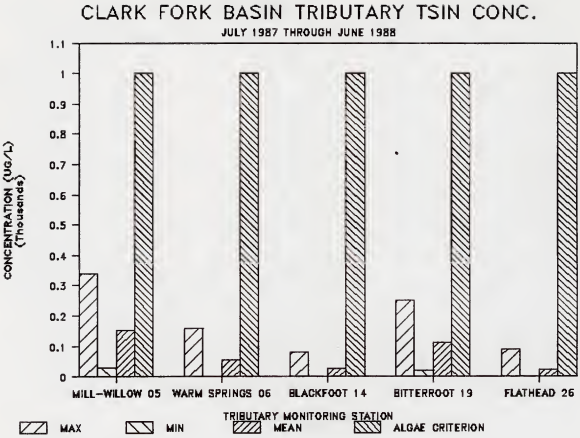


FIGURE 63

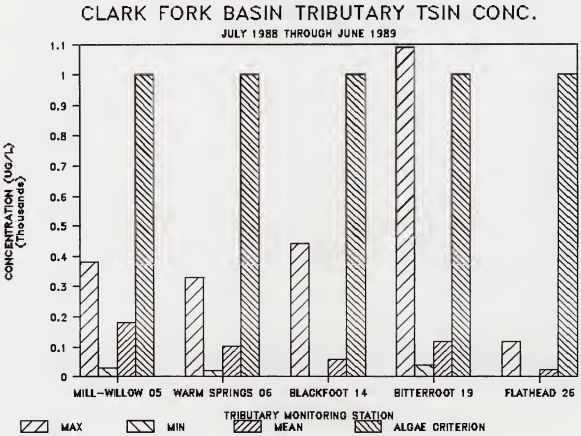


FIGURE 64

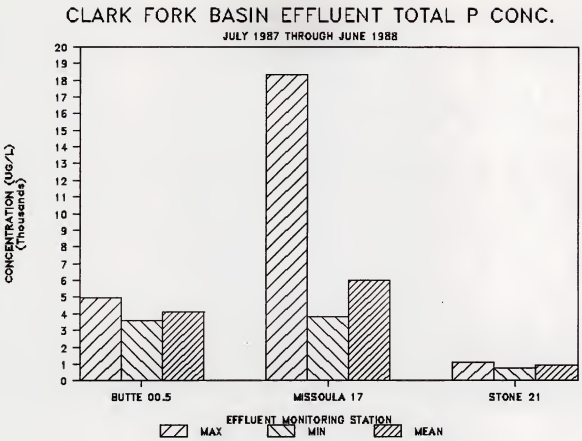


FIGURE 65

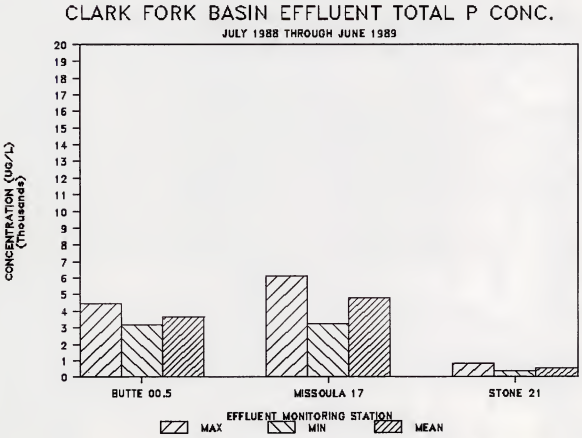


FIGURE 66

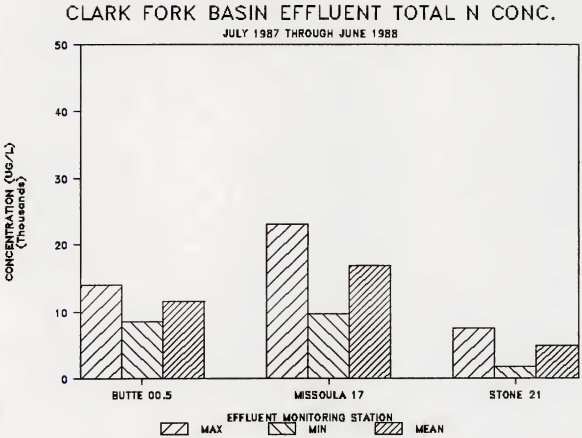


FIGURE 67

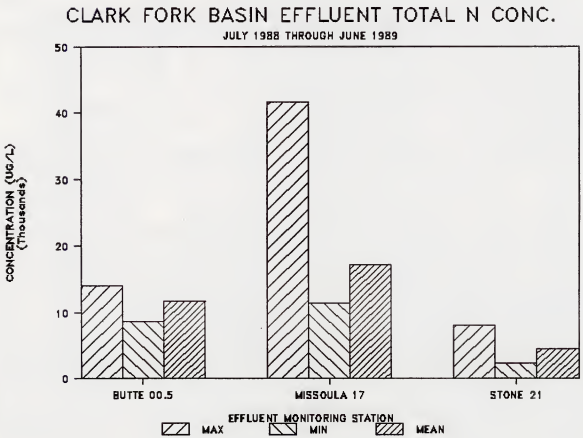


FIGURE 68

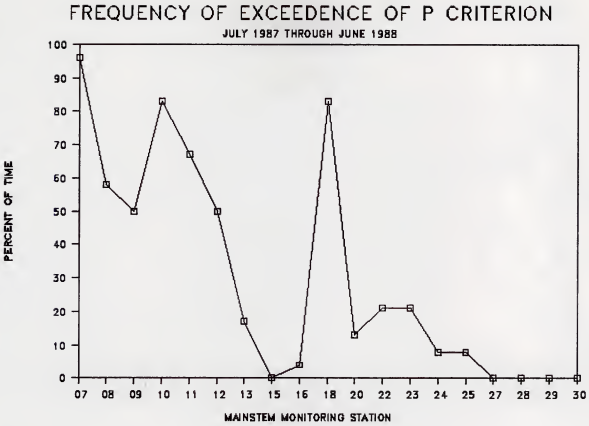


FIGURE 69

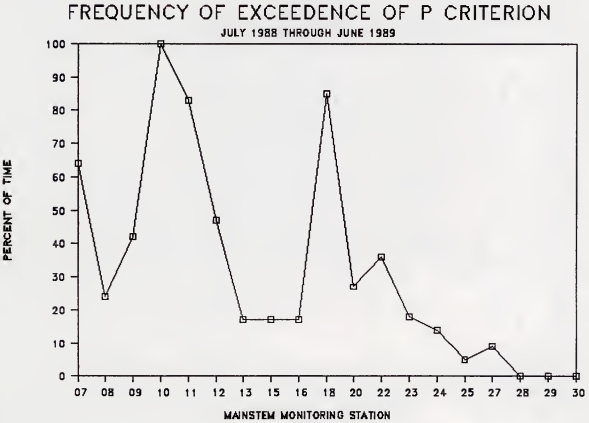


FIGURE 70

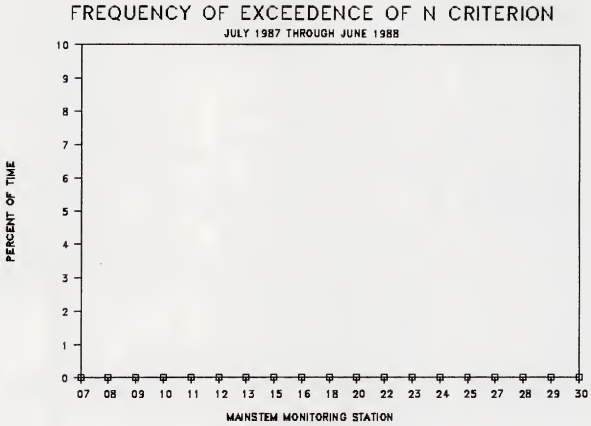


FIGURE 71

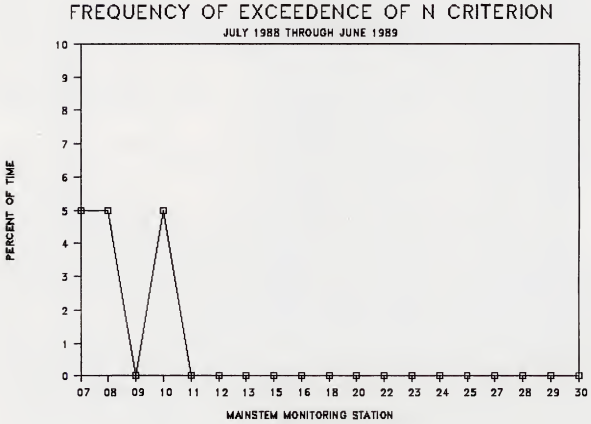


FIGURE 72

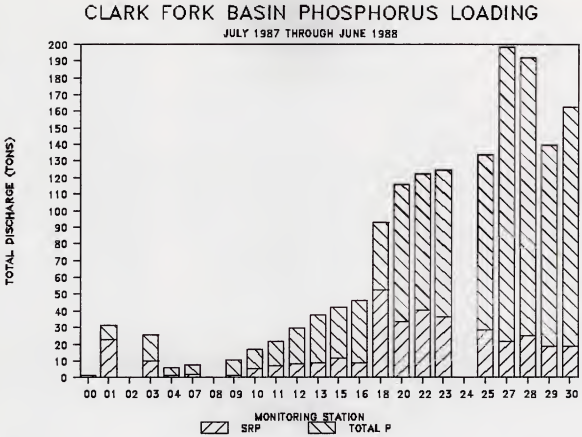


FIGURE 73

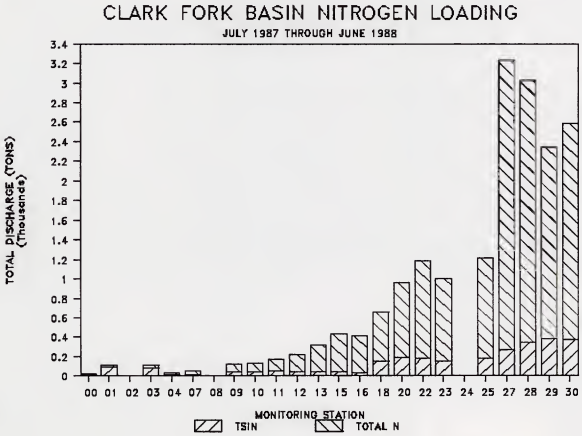


FIGURE 74

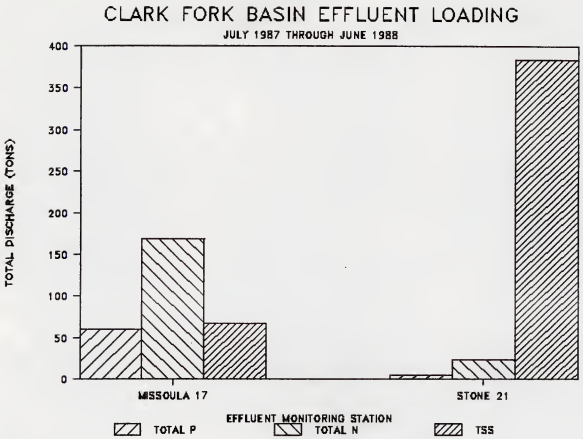

CLARK FORK BASIN EFFLUENT LOADING
JULY 1987 THROUGH JUNE 1988
TOTAL DISCHARGE (TONS)
400
350
300
250
200
150
100
50
0
MISSOULA 17
STONE 21
EFFLUENT MONITORING STATION
TOTAL P
TOTAL N
TSS

FIGURE 75

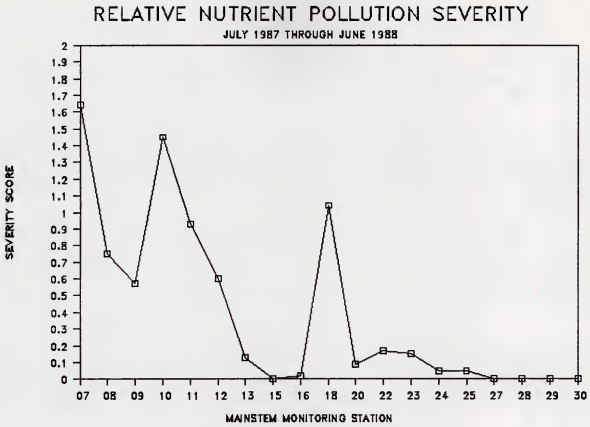
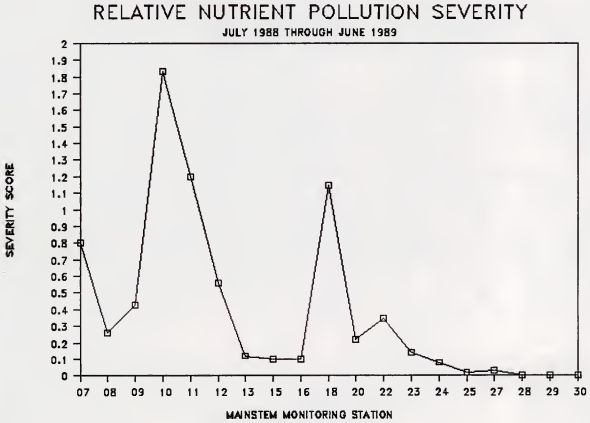


FIGURE 76



3.4 Suspended Sediment

Measured concentration ranges and mean values for total and volatile suspended sediment during FY 1988-1989 are tabulated in Tables 10 and 11.

Graphs of maximum, minimum and mean total suspended sediment concentrations and a criterion value for the protection of fisheries and aquatic communities (U.S. EPA, 1973) are presented in Figures 77-78 (Silver Bow Creek), 79-80 (Clark Fork mainstem), 81-82 (Clark Fork tributaries) and 83-84 (wastewater discharges).

Estimated total annual discharges or loads of suspended sediment in Silver Bow Creek and the Clark Fork River during FY 1988 are given in Figure 85. Estimated FY 1988 loads of suspended sediment in the Missoula and Stone Container Corporation wastewater discharges are displayed in Figure 74.

Suspended sediment pollution severity scores for Clark Fork mainstem monitoring stations are given in Figures 86, 87 and 90.

Individual suspended sediment data appear in Appendices E and F.

Table 10. Fiscal Year 1988 Clark Fork Basin Suspended Sediment Concentration Data Summary

Station Number	N=1	Measured Concentration (mg/l) July 1987 through June 1988 Total Suspended Sediment (TSS) Conc. Range	Mean	Volatile Suspended Sediment (VSS) Conc. Range	Mean
I. Mainstem Stations					
07	17	2.4- 54.9	7.2	1.0-14.4	2.8
08	17	2.8- 51.3	12.5	0.7- 9.8	3.2
09	17	3.2- 52.5	18.8	1.2- 9.4	3.7
10	17	5.9- 64.9	19.8	1.7-10.5	4.1
11	17	2.9- 78.7	18.8	0.8-12.6	3.5
12	17	1.3-104.6	21.4	0.5-16.2	3.7
13	17	2.8- 72.9	15.6	0.9-12.3	3.0
15	17	1.3- 25.1	6.1	0.5- 4.4	1.4
16	17	1.3- 25.2	7.8	0.5- 4.2	1.7
18	17	1.5- 25.9	7.7	0.6- 4.5	1.7
20	17	1.4- 41.9	8.5	0.6- 5.2	1.8
22	17	1.8- 44.0	9.8	0.9- 5.8	2.1
23	17	1.5- 49.7	9.6	0.7- 6.4	2.0
24	17	1.2- 46.2	9.4	0.6- 5.8	1.9
25	17	0.6- 40.1	7.8	0.3- 5.3	1.6
27	17	0.9- 35.2	6.5	0.4- 5.6	1.2
28	17	1.0- 19.9	4.9	0.4- 3.3	1.0
29	17	0.5- 2.9	1.4	0.4- 1.0	0.6
30	17	0.3- 3.1	1.6	0.3- 1.0	0.6
II. Tributary Stations					
00	17	3.5- 47.5	10.9	1.3- 7.8	2.5
01	17	4.5- 42.4	15.0	1.9-15.1	5.3
02	17	6.0- 45.4	14.9	2.2- 8.3	3.6
03	17	9.1- 60.6	17.5	2.6-13.5	4.9
04	17	1.4- 18.3	5.2	0.9-12.6	3.1
05	17	3.1- 43.8	7.3	1.1-10.1	2.4
06	17	0.4-136.7	8.7	0.3-29.4	2.2
14	17	0.6- 30.9	5.3	0.5- 3.9	1.3
19	17	1.0- 36.2	8.5	0.5- 5.2	1.8
26	17	0.7- 56.4	7.2	0.4- 4.0	0.9
III. Effluent Stations					
00.5	14	3.4-11.7	6.0	3.4-11.1	5.6
17	17	2.7-15.9	6.8	2.3-14.0	6.3
21	7	48.9-84.8	73.6	43.0-77.8	63.6

Table 11. Fiscal Year 1989 Clark Fork Basin Suspended Sediment Concentration Data Summary

Station Number	N=[1]	Measured Concentration (mg/l) July 1988 through June 1989 Total Suspended Sediment (TSS) Conc. Range	Mean	Volatile Suspended Sediment (VSS) Conc. Range	Mean
I. Mainstem Stations					
07	15	2.3-26.8	7.1	1.3- 6.8	2.5
08	15	2.4-24.3	11.8	1.1- 5.8	3.1
09	15	2.9-44.3	21.0	0.9- 7.8	4.2
10	15	5.1-62.6	25.1	1.5-11.3	4.9
11	15	2.6-53.2	19.9	0.8- 9.5	4.0
12	15	4.4-69.5	21.2	1.1-10.8	3.8
13	15	3.7-39.3	12.6	1.2- 6.4	2.7
15	15	3.0-39.0	12.1	1.0- 7.6	2.4
16	15	3.1-37.9	12.8	0.9- 5.3	2.5
18	15	3.2-39.2	13.1	1.0- 5.2	2.6
20	15	2.4-34.9	10.2	0.8-12.3	3.1
22	15	3.0-36.4	13.0	0.9- 6.1	2.6
23	15	2.6-40.3	10.8	0.9- 6.3	2.3
24	15	1.8-50.3	10.0	0.8- 6.8	2.1
25	15	2.4-42.4	8.0	1.0- 6.7	1.9
27	15	1.6-33.9	8.9	0.6- 5.5	1.6
28	15	1.7-36.3	8.8	0.6- 4.0	1.5
29	15	0.6-11.4	2.7	0.4- 1.7	0.8
30	15	0.9-11.8	2.9	0.5- 1.9	1.0
II. Tributary Stations					
00	15	3.6-20.0	9.2	1.2- 3.9	2.4
01	15	6.6-37.1	18.4	2.5- 9.4	5.2
02	15	8.4-43.3	14.6	2.8- 8.4	4.2
03	15	8.3-93.9	21.2	2.5-18.3	6.2
04	15	1.3-34.1	6.5	0.7- 8.4	2.6
05	15	3.5-11.2	6.7	1.1- 4.1	2.2
06	15	0.6-11.0	3.1	0.5- 2.9	1.3
14	15	1.5-42.1	7.8	0.7- 4.5	1.8
19	14	1.1-24.8	6.6	0.6- 4.3	1.6
26	15	0.9-97.6	13.3	0.4- 6.3	1.4
III. Effluent Stations					
00.5	15	2.9- 9.6	5.1	2.2- 8.7	4.6
17	15	1.9-21.4	7.1	1.9-19.1	6.5
21	10	19.5-99.6	40.0	17.4-90.3	35.2

FIGURE 77

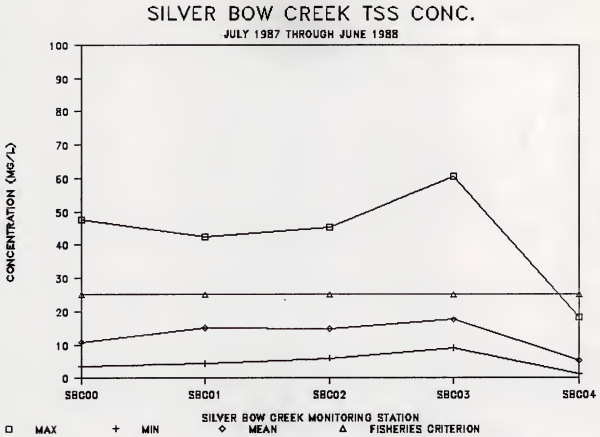


FIGURE 78

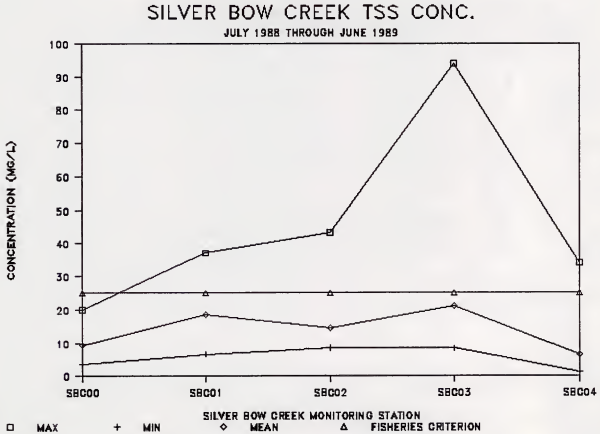
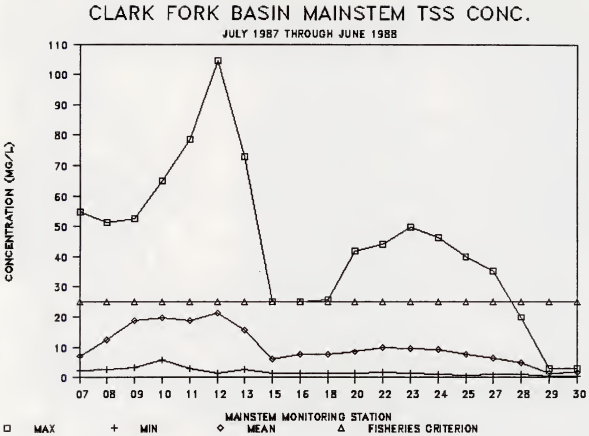


FIGURE 79



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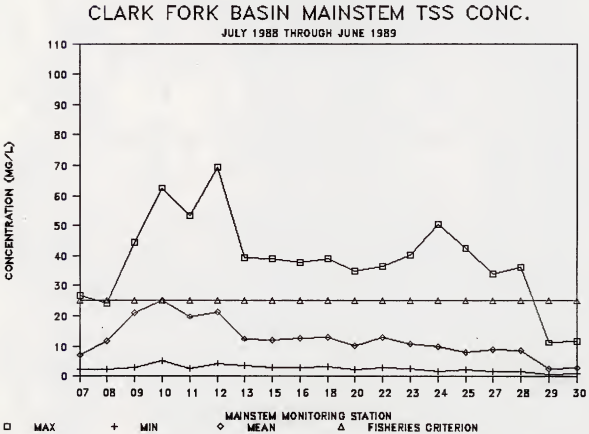


FIGURE 81

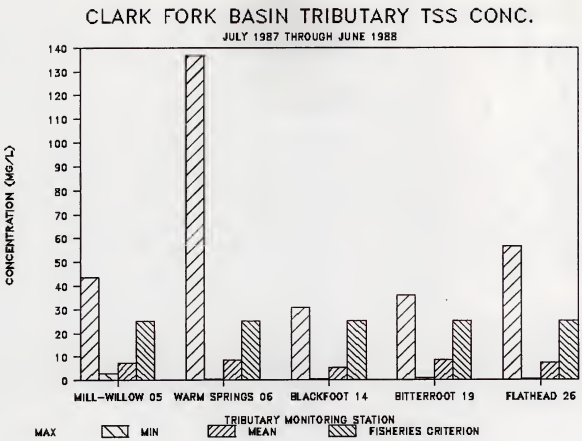


FIGURE 82

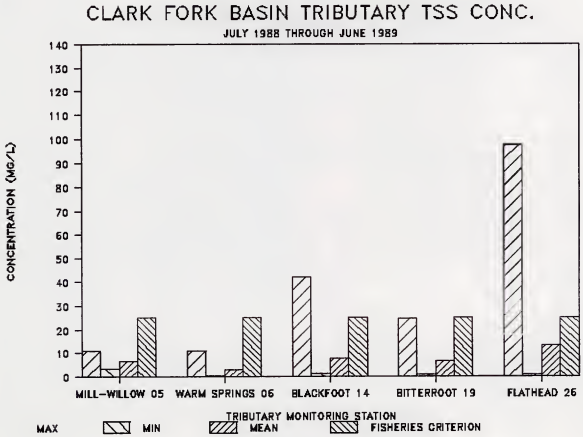


FIGURE 83

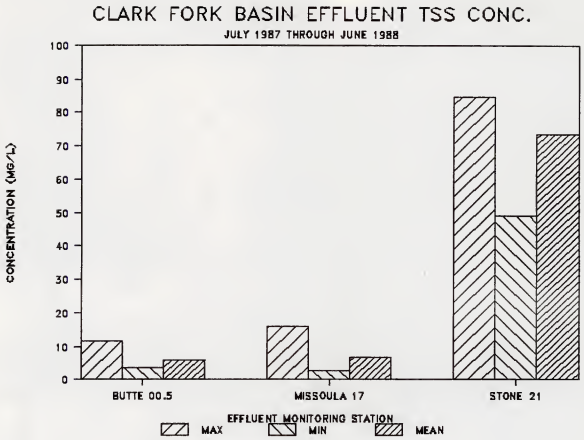
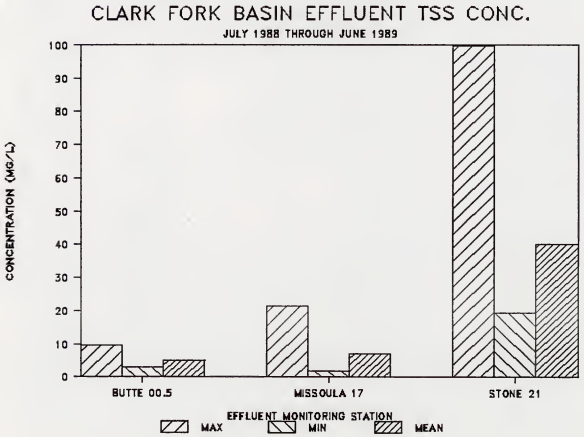


FIGURE 84



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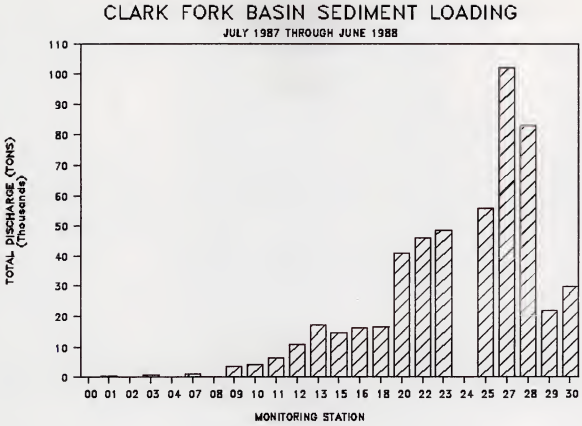

CLARK FORK BASIN SEDIMENT LOADING
JULY 1987 THROUGH JUNE 1988
TOTAL DISCHARGE (TONS)
(Thousands)
110
100
90
80
70
60
50
40
30
20
10
0
00 01 02 03 04 07 08 09 10 11 12 13 15 16 18 20 22 23 24 25 27 28 29 30
MONITORING STATION

FIGURE 86

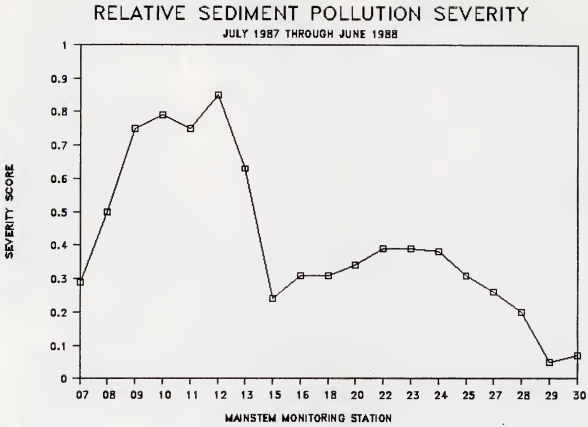


FIGURE 87

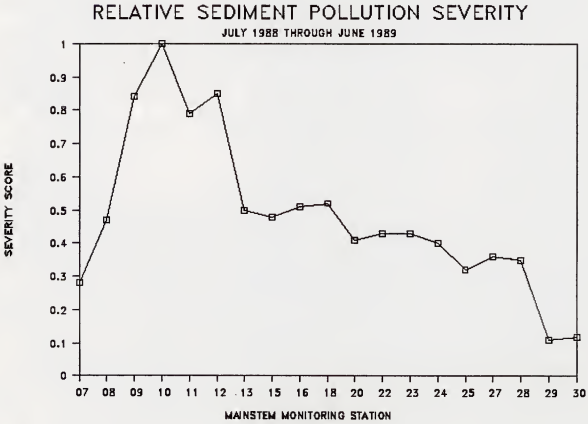


FIGURE 88

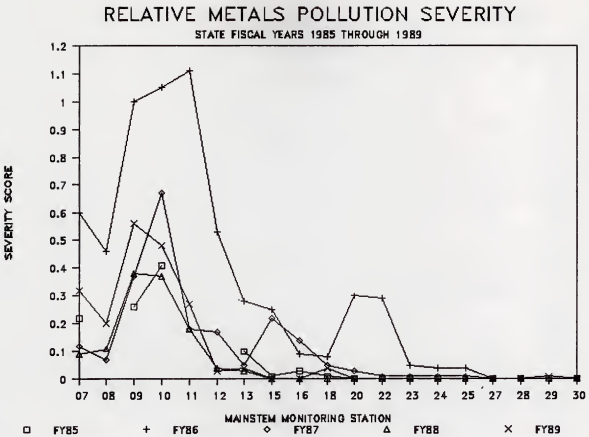


FIGURE 89

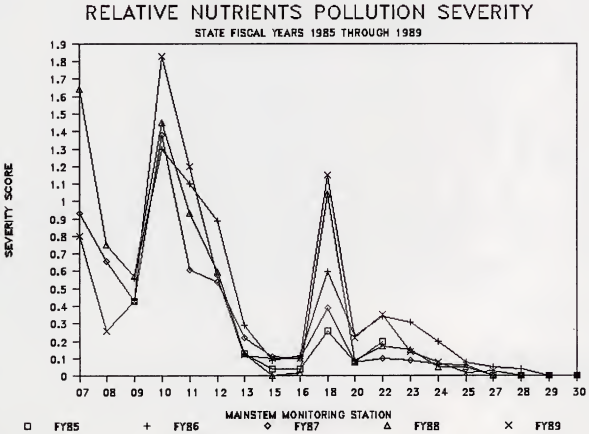
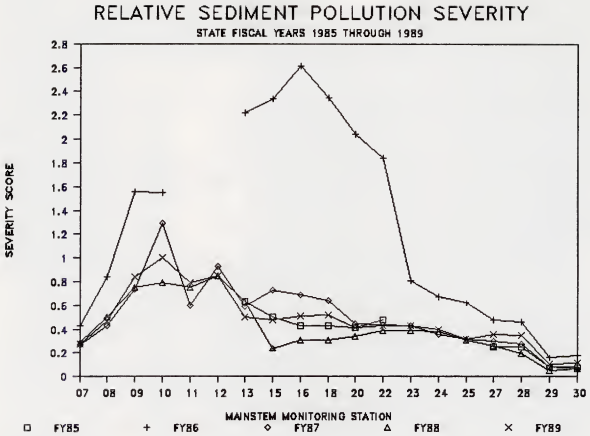


FIGURE 90


RELATIVE SEDIMENT POLLUTION SEVERITY
STATE FISCAL YEARS 1985 THROUGH 1989
SEVERITY SCORE
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
07 08 09 10 11 12 13 15 16 18 20 22 23 24 25 27 28 29 30
MAINSTEM MONITORING STATION
FY85
FY86
FY87
FY88
FY89

4. DISCUSSION

4.1 Streamflows

Drought conditions prevailed throughout much of the western United States, including most of the Clark Fork Basin, during all of FY 1988 and the first quarter of FY 1989. Many western streams had less discharge than during the 1977 drought and some experienced record low flows. The reasons for the low flows were low winter snowpack, unseasonably early melt of that snowpack and prolonged periods of well-above-average temperatures (USGS, 1987; 1989). Normal snow accumulations in the fall and winter of 1988-1989, a more protracted spring runoff and summer rains finally reversed the situation in western Montana. As a result of the prevailing weather conditions and low streamflows in the Clark Fork Basin (Figures 5-7, FY 1989 data not yet available), the assessments of streamflow - dependent variables in this report are not representative of more normal runoff years.

As shown in Figure 2, streamflows in the headwaters of the Clark Fork are small compared to the middle and lower river segments. The volume of water in the river at any given location is an important variable in determining water quality. Tributary inflows, especially those of the Blackfoot, Bitterroot and Flathead rivers (Figure 3) greatly increase the size of the Clark Fork and help to dilute pollutants downstream from their sources. Figure 4 gives a relative comparison of the average volume discharged by the three monitored wastewater discharges to the Clark Fork. Note that the allowable wastewater discharge rate for the Stone Container Corporation kraft mill is controlled by streamflows in the river (MDHES, 1986b). Stone's average wastewater flow rate would be higher in normal runoff years, while flows from the Butte and Missoula WWTP's can be expected to be much the same as those shown.

4.2 Metals

The discussion that follows reviews measured metals concentrations, estimated metals loads and metals pollution severity scores for Clark Fork Basin monitoring stations during the FY 1988-1989 period.

The U.S. EPA has established concentration criteria values for copper, zinc, arsenic, cadmium and lead that should not be exceeded in order to protect sensitive freshwater aquatic organisms. The values are water hardness-dependent for copper, zinc, cadmium and lead and are fixed for arsenic. The criteria give two values -- a chronic toxicity value, expressed as a 4-day average concentration, and an acute toxicity value, expressed as a one-hour average concentration, that should not be exceeded more than once every three years. The chronic toxicity criteria

values for copper, zinc, cadmium and lead, at a water hardness of 100 mg/l (as $CaCO_3$), are 12, 110, 1.1, and 3.2 µg/l, respectively. Acute toxicity criteria for the same metals are 18, 120, 3.9, and 82, respectively. The fixed chronic and acute toxicity criteria for arsenic are 190 and 360 µg/l, respectively (U.S. EPA, 1986).

Estimated metals loads provide a measure of the total weights of metals discharged per unit of time. These data reveal the sources of metals in the basin (where loads increase from one station to another) and identify sinks (where losses occur from one station to another).

The metals pollution severity scores provide a comparison of the relative degree of metals-associated problems from station to station and from year to year.

Silver Bow Creek from Butte to the Warm Springs treatment ponds (monitoring stations 00-03) continued to be seriously polluted with copper and zinc throughout the two year monitoring period (Figures 8-11). Cadmium and lead concentrations, while not monitored in FY 1988, were also shown to be serious problems in Silver Bow Creek during FY 1989 (Figures 13-14). The chronic toxicity criteria for copper, zinc and cadmium were routinely exceeded (75-100 percent of the time) at all monitoring stations above the treatment ponds, while acute toxicity criteria for copper and zinc were always surpassed. The chronic toxicity criterion for lead was exceeded at stations downstream of the Colorado Tailings (Stations 01-03).

Metals concentrations in Silver Bow Creek were the highest of all Clark Fork Basin monitoring locations. Average concentrations regularly exceeded the chronic criteria values by from two to 15 times. Overall, mean metals concentrations were slightly higher in FY 1989 than in FY 1988 and were fairly comparable to those measured in FY 1987 (Ingman, 1987). However, significantly greater peak metals concentrations were documented in FY 1987 than in either of FY 1988 or FY 1989.

Arsenic concentrations were commonly an order of magnitude less than either copper or zinc. Exceedences of aquatic life criteria and drinking water standards were not documented as occurring in Silver Bow Creek or the mainstem Clark Fork during FY 1988 (Figures 12 and 19). Arsenic monitoring was discontinued in FY 1989.

Sources of metals within the Silver Bow Creek drainage can be delineated by examining the metals load plots in Figures 36 and 37. During FY 1988, mine tailings and/or contaminated groundwater inputs between the Colorado Tailings and the Warm Springs treatment ponds (sources between monitoring stations 01 and 03) contributed approximately 3.7 tons of copper and 7.2 tons

of zinc to Silver Bow Creek. These levels of loading are considerably less than in either of FY 1986 or FY 1987, presumably as a result of the drought and the resulting low streamflows. The Colorado Tailings area was responsible for inputs of about 2.8 tons of copper and 11.8 tons of zinc to Silver Bow Creek during FY 1988. Sources of metals above the uppermost Silver Bow Creek monitoring station (station 00) contributed roughly 2.8 tons and 8.2 tons of copper and zinc, respectively, to the drainage. Sources of metals in FY 1989 have not been evaluated pending the availability of streamflow data.

The Butte municipal sewage discharge (station 00.5) periodically contained high concentrations of copper and zinc. The primary source of those metals was presumed to be infiltration of contaminated shallow groundwater into sewer mains. Shallow groundwater at the WWTP also had to be pumped from time to time (Bill Pasco, pers. comm.). During those events the WWTP discharge contained concentrations of zinc greater than those in Silver Bow Creek. Instances of this were documented as occurring in September of 1987 and 1988. Thus, the Butte WWTP discharge periodically was a significant source of metals to Silver Bow Creek.

As in the past, the Warm Springs treatment ponds were extremely effective at reducing metals loads, concentrations and toxicity in Silver Bow Creek. During FY 1988, Silver Bow Creek copper loads were reduced nearly 19 fold while zinc loads were reduced nearly 13 fold as a result of treatment provided by the ponds (Figures 33 and 37, Stations 03 vs. 04). These metals removal efficiencies were about twice those of any of the previous three years, indicating that retention times, as influenced by streamflow rates, are an important factor in the level of metals treatment provided. During FY 1988, the treatment ponds removed an estimated nine tons of copper and 26 tons of zinc from Silver Bow Creek.

Metals concentrations in Silver Bow Creek, after passing through the pond system, were generally an order of magnitude less (Figures 8-13). However, the ponds were not as effective at reducing concentrations of lead (Figure 14).

In FY 1988, exceedences of the chronic and acute toxicity criteria for copper occurred 21 and four percent of the time, respectively in the Warm Springs Pond Two discharge. The zinc criteria were never exceeded. Annual average concentrations for copper and zinc were about two-thirds and one-third, respectively, of the chronic toxicity criteria values. In FY 1989, mean copper and zinc concentrations in the pond discharge were two to two and a half times larger than in FY 1988. Chronic toxicity criteria for copper, zinc, cadmium and lead were exceeded 29, 14, 13 and 14 percent of the time, respectively. Acute toxicity values for copper and zinc were surpassed 18 and

14 percent of the time. Metals concentrations in the pond discharge in March 1989 were among the highest measured in a five year period, following a rapid thaw in the Silver Bow Creek drainage at a time when the ponds were under a heavy layer of ice. Past monitoring data indicates that the metals treatment efficiency of the ponds is reduced in winter. The March metals data, and concentrations measured during the spring runoff period, strongly influenced the FY 1989 average values and accounted for all of the documented exceedences of the toxicity criteria. Spring of 1989 experienced a more normal snowmelt runoff than that of 1988.

The combined flows of Mill and Willow creeks (station 05) join Silver Bow Creek a short distance below the Warm Springs Ponds. The quality of this stream is generally comparable, on the average, to that of Silver Bow Creek below the ponds. The creek flows in a manmade ditch along the edge of the Warm Springs pond system. The channel was cut through historic tailings deposits left by Silver Bow Creek before the ponds were built and contains newer tailings carried in by Silver Bow Creek during pond bypass events. The tailings deposits in and along the Mill-Willow Bypass channel are an important source of metals during snowmelt runoff and after heavy rains. Six fish kills have been documented as occurring in the Mill-Willow Bypass since 1983, following heavy summer thunderstorms.

Beginning in 1988, the Anaconda Company has installed a temporary dam in the bypass channel each summer which diverts the streamflow into the Warm Springs Pond via an existing inverted siphon. The dam is located below most of the streamside tailings and prevents untreated stormwater runoff from entering the mainstem Clark Fork River. While the dam diverts all of the upstream summer flow, seepage from the Warm Springs Ponds dikes and discharges from an adjacent wildlife management pond maintain constant flows at our monitoring station in the lower end of the channel.

During the FY 1988-1989 monitoring period, only copper exceeded the aquatic life toxicity criteria in the Mill-Willow Bypass (Figures 22-28). Exceedences of the criteria, which occurred more than a third of the time in each year, were associated with rains or thaw events. The stream also carried the highest recorded arsenic concentrations of stations monitored. Although aquatic life criteria were never approached, the more conservative federal drinking water standard of 50 µg/l was exceeded on one occasion. Lowest metals concentrations were measured in July and August 1988, when the diversion dam was in place.

The mainstem Clark Fork River begins at Silver Bow Creek's junction with Warm Springs Creek. Warm Springs Creek is relatively metals free (Figures 22-28), except when unusually

high streamflows contact historic smelter wastes in its floodplain. Only one exceedence of the copper toxicity criterion was documented in FY 1988-1989, during a peak flow event on May 17, 1988. Warm Springs Creek dilutes metals concentrations in the Clark Fork and increases its water hardness and alkalinity, which buffers the effects of metals. Warm Springs Creek drains a limestone formation which contributes to its high hardness and moderate alkalinity. Unfortunately, Warm Springs Creek is severely dewatered for irrigation. July through September streamflows averaged only 3.1 cfs during FY 1988-1989.

The Clark Fork at its point of origin exhibits generally only fair water quality from the standpoint of metals concentrations. The copper chronic toxicity criterion was exceeded 13 percent of the time at monitoring station 07 in FY 1988, while the copper, zinc and lead chronic criteria were exceeded 26, 9 and 9 percent of the time, respectively, in FY 1989 (Figures 29-35). The acute criteria for copper and zinc were also occasionally exceeded. In general, excursions from the criteria during the monitoring period tended to be small. An exception was in March 1989 when a poor quality Warm Springs Pond Two discharge was responsible for five-fold and two-fold exceedence of the chronic toxicity criteria for copper and zinc, respectively. Metals concentrations associated with this event were the highest seen in the mainstem Clark Fork during the two-year monitoring period.

From the headwaters monitoring station 07 to about 15 miles below Deer Lodge (station 10), a distance of about 40 river miles, the Clark Fork exhibits progressively deteriorating water quality during most years (Ingman, 1988a). This is contrary to the Montana Water Quality Standards which reflect improved conditions below Deer Lodge. In FY 1988-1989, mean metals concentrations increased only slightly in this reach, in the case of copper and zinc, or not at all, in the case of cadmium and lead. Although the increase in instream metals concentrations in this reach were small during this monitoring period, they were sufficient to cause more frequent exceedence of the standards (Figures 29-30). The chronic toxicity criterion for copper was exceeded about 40 to 50 percent of the time at monitoring stations 09 and 10 during FY 1988-1989. Estimates of FY 1988 metals loading (Figures 36-37) indicate that copper and zinc loads were from two to three times higher at monitoring station 10 than at station 07. The sources of the additional metals in this reach of the river are streamside and stream channel tailings deposits that are scattered throughout the upper Clark Fork floodplain. Another possible, but uninvestigated, source of metals is groundwater entering the river in known recharge areas.

Mean metals concentrations in the mainstem upper Clark Fork usually tend to peak between Deer Lodge and the Little Blackfoot River (stations 09-10), followed by a rapid downstream

decline. This trend is the result of incoming tributaries, such as the Little Blackfoot and Blackfoot rivers and Rock Creek, which dilute metals concentrations, and less significant sources of additional metals. The same trend was exhibited in FY 1988-1989 (Figures 15-21). The metals load figures (Figures 36-37) show increases in copper and zinc loading during FY 1988 as far downstream as monitoring stations 12 or 13 (Bonita and Turah, respectively) These areas delineate the downstream-most extent of significant metals sources associated with the historic mining activities in the headwaters. It is interesting to note that the FY 1988 mainstem metals load figures are about half the estimated average loads for the FY 1985-1988 period, indicating low metals production and transport during drought years.

Clark Fork metals concentrations are an infrequent problem from the Blackfoot River confluence (bracketed by stations 13 and 15) downstream to the Idaho border (station 30). Metals criteria were rarely exceeded at any monitoring station below the Blackfoot River, including tributaries, during FY 1988-1989 (Figures 22-30) and exceedences were usually slight.

Elevated metals levels have occurred below Milltown Dam in past years as a result of operational drawdowns, high water events and reconstruction activities. FY 1989 was no exception. During the summer of 1988, metals concentrations were temporarily increased below the dam (station 15) relative to upstream stations (stations 13 and 14) as a result of powerhouse reconstruction activities. However, based on our monitoring the increases were not sufficient to cause exceedences of toxicity criteria. Metals loading figures (Figure 36-37) indicate that Milltown Dam acted as a net metals sink during FY 1988.

Two individual exceedences of the cadmium chronic criterion and three exceedences of the lead chronic criterion were documented in the middle or lower mainstem Clark Fork during the soft water spring runoff period of FY 1989 (Figures 34-35). In each case the measured concentrations were exactly at, or very slightly above, the standard. Given the low cadmium and lead criteria values for soft waters and the laboratory precision and accuracy of the test at low concentrations, concern is not warranted at this time.

Of the two monitored wastewater discharges to the middle Clark Fork, only the Missoula WWTP has been shown to contribute metals to the Clark Fork. On several occasions in FY 1988, the WWTP effluent contained copper concentrations in excess of chronic or acute toxicity criteria. In past years, zinc has been a periodic problem. The presumed sources of metals in the discharge are copper and galvanized plumbing throughout

the city of Missoula. Background Clark Fork metals concentrations are low enough, and dilution of the effluent is high enough, to prevent instream problems downstream of the discharge.

The metals pollution severity scores presented in Figures 38, 39 and 88 provide a graphic picture of the relative degree of metals pollution in the Clark Fork from its headwaters to Idaho during each of FYs 1985 through 1989. Metals were a more serious problem in the upper Clark Fork in FY 1989 as compared to FY 1988, due to a poor quality discharge from the Warm Springs Ponds and higher spring streamflows. In both years metals problems were almost nonexistent from below the Blackfoot River to the Idaho border. Overall, conditions in the Clark Fork River relative to metals concentrations were much better during each of the last two years than in years of higher streamflows, such as FY 1986.

4.3 Nutrients

This section reviews measured nitrogen (N) and phosphorus (P) concentrations, estimated N and P loads and nutrient pollution severity scores for Clark Fork Basin monitoring stations during FYs 1988-1989.

Of the many nutrients required by algae and other aquatic plants, nitrogen and phosphorus are the two elements usually in the shortest supply in natural waters relative to the needs of the plant. This means that the growth of algae is often controlled by the concentration of nitrogen or phosphorus, or both, in the water column. The U.S. EPA has established criteria values for total inorganic nitrogen and total phosphorus that should not be exceeded in order to prevent excessive developments of attached algae in rivers and to prevent eutrophication in lakes which are fed by rivers. These values are 1000 µg/l for nitrogen (water quality criteria matrix in MDHES, 1986) and 50 µg/l for phosphorus (U.S. EPA, 1986). While the criteria may not apply equally well in all situations and do not consider other limitations to algal growth, they are valuable as a general benchmark against which measured instream nutrient concentrations can be compared. The criteria do not apply to wastewater discharges.

Another nutrient, ammonia-nitrogen is frequently present in wastewater discharges. While ammonia, or its degradation products, is readily available for algal uptake and can contribute to nutrient enrichment problems, the primary concern is toxicity to aquatic life. At high enough concentrations and under certain conditions of stream temperature

and pH, the potential exists for ammonia toxicity downstream of wastewater discharges in the Clark Fork Basin. The nutrient monitoring data have also been reviewed for evidence of toxicity problems created by the presence of ammonia-nitrogen.

Estimated nutrient loads provide a measure of the total weights of nitrogen and phosphorus discharged per unit of time. These data allowed us to gage the relative importance of the three monitored wastewater discharges in the basin and to compare nutrient loading from tributaries and at various locations along the mainstem.

The nutrient pollution severity scores provided a measure of what reaches of the Clark Fork were most impacted by nutrients, and how variable the problem was from year to year.

Silver Bow Creek from Butte to the Warm Springs treatment ponds suffered from a serious nutrient pollution problem on a year around basis during FY 1988-1989. Measured concentrations of phosphorus and nitrogen (Figures 40-47) were an order of magnitude higher than at any of the other stream monitoring stations in the Clark Fork Basin. Most of the measured phosphorus and nitrogen was present as soluble, bioavailable forms (SRP and TSIN). The EPA phosphorus and nitrogen criteria to prevent the development of nuisance algae and to control eutrophication were routinely exceeded (nearly 100 percent of the time) by a large margin at most monitoring locations on the creek. Average phosphorus and nitrogen concentrations exceeded the criteria by up to 29 and 5 times, respectively, at some locations. Concentrations were comparably high in each of FYs 1988 and 1989.

Highest nutrient concentrations in Silver Bow Creek occurred at monitoring station 01, below the Colorado Tailings. The station is located downstream of the Butte municipal wastewater discharge (station 00.5), which is the principal source of nutrients to the creek. This is demonstrated by the load plots in Figures 68-69 (stations 00 and 01 bracket the Butte discharge). During periods of low streamflow, about half of the flow at monitoring station 01 consisted of sewage effluent. The sources of nutrients contributing to high concentrations in Silver Bow Creek upstream of the Butte discharge are unknown.

From monitoring station 01 downstream to the Warm Springs Ponds, nutrient concentrations and loads declined as streamflows increased and as some biological assimilation of nutrients probably occurred. However, concentrations remained sufficiently high to categorize the stream as grossly nutrient-polluted. It is worth noting that despite perpetual exceedences of the nutrient criteria, Silver Bow Creek failed to develop extensive algae. Algal bioassays conducted by the EPA (Greene

et. al., 1986) indicated that Silver Bow Creek algal growth potential is limited by metals toxicity, most likely copper. Copper sulfate is a widely used algicide in industrial and potable water supplies.

The Butte sewage effluent is also a source of ammonia to Silver Bow Creek. EPA chronic ammonia toxicity criteria for salmonids (U.S. EPA, 1986) were exceeded from 17 to 82 percent of the time from the Butte sewage outfall down to the Warm Springs Ponds. Ammonia evaluations and data are included in Appendices C and D. The metals and ammonia problems effectively limit the establishment of a fishery in Silver Bow Creek.

The Warm Springs Ponds were nearly as effective at reducing Silver Bow Creek nutrient concentrations and loads (Figures 40-47, 68-69, stations 03 vs. 04) as they were for metals. On the average, nitrogen and phosphorus concentrations and loads were four to six-fold less in the pond outlet as compared to Silver Bow Creek above the ponds during fiscal years 1988-1989. Nutrient removal efficiencies were slightly higher in each of these two years than during either FY 1986 or 1987. Biological assimilation and settling of solids probably were responsible for the nutrient reductions. Treatment appeared to be more effective during the longer retention times associated with a drought year. During FY 1988, the ponds removed some 13 tons of phosphorus (of which nearly a fourth was bioavailable P) and 52 tons of nitrogen (of which 94 percent was bioavailable) from Silver Bow Creek.

The ponds effectively reduced average nitrogen concentrations to levels below the EPA criterion. However, individual values occasionally exceeded that standard. One small-scale exceedence was documented in February 1988 while three slight exceedences were measured in the January to April period of 1989. Phosphorus problems were more widespread. Measurements of total phosphorus in the pond discharge exceeded the EPA criterion 80 to 100 percent of the time in FYs 1988-1989, while mean concentrations averaged nearly three times the threshold value.

Nutrient concentrations in the Mill-Willow Bypass and especially Warm Springs Creek were significantly lower than those in Silver Bow Creek (Figures 56-63). Each of these tributaries helped to reduce the nutrient concentrations in the mainstem Clark Fork at its point of origin. Conversely, the Mill-Willow Bypass contained elevated concentrations of nitrogen when compared to other Clark Fork tributaries (excluding Silver Bow Creek). The Mill-Willow Bypass flows adjacent to an unsewered suburb of Anaconda (Opportunity) with a shallow groundwater table (Ingman, 1989a).

Nutrient concentrations in the mainstem upper Clark Fork showed a distinct trend in FYs 1988-1989, and one was that was comparable to past years (Ingman, 1988b). Mean phosphorus concentrations declined from the headwaters downstream to Deer Lodge (Figures 48-51, stations 07-09). This was attributable to increasing distance from sources (primarily the Butte WWTP) and increased dilution from incoming tributaries. Mean nitrogen concentrations, on the other hand, remained stable or increased slightly downstream to Deer Lodge. This was attributable to additional sources of nitrogen in this reach of river. Past work has indicated that most of the tributaries to the upper Clark Fork, including Lost, Racetrack and Dempsey creeks, contain elevated concentrations of nitrogen. Agricultural sources, including contaminated irrigation return flows, are suspected. The Galen sewage lagoon also discharges to this section of the river but its nutrient loading is small compared to the tributaries (Ingman, 1989a).

Between Deer Lodge and the Little Blackfoot River confluence (stations 9-10), notable spikes in phosphorus and nitrogen concentrations occurred. Mean nutrient concentrations here were among the highest found anywhere in the river. The primary source of nutrients in this reach of the river is the Deer Lodge municipal sewage lagoon discharge (Ingman, 1989a). A possible but uninvestigated additional source of nitrogen is the significant recharge of groundwater to the river below Deer Lodge (Tom Brooks, USGS, pers. comm.). Mean nutrient concentrations steadily declined from monitoring station 10 downstream to Missoula, despite additional nutrient sources (e.g. Phillipsburg and Drummond lagoon discharges, Gold Creek, [Ingman, 1989a]). Apparently, the increasing volume in the river from incoming tributaries (Figure 2) and biological assimilation of nutrients were sufficient to more than offset the influences of new sources. The largest tributary in this reach is the Blackfoot River and its quality is excellent with respect to nutrients (Figures 56-63).

When we compare the measured nutrient concentrations in the upper mainstem Clark Fork to the EPA criteria, it is apparent that the river is enriched. Phosphorus concentrations routinely exceeded the criterion (Figures 48-49, 68-69) downstream to the Rock Creek confluence (bracketed by stations 12 and 13). In the absence of the high metals concentrations of Silver Bow Creek (which have been shown to limit algae), filamentous green and diatom algae proliferated throughout the upper Clark Fork during this study period. Nitrogen concentrations only rarely exceeded the EPA criterion.

In the middle Clark Fork, from Milltown Dam downstream to the Flathead River (stations 15-25), nutrient concentrations were variable as a result of dilution from incoming clean water tributaries and the influences of several major new sources of

nutrients. Lowest and comparable mean nutrient concentrations were measured at the upper-most and lower-most ends of the middle river segment (stations 15 and 25, respectively) during each of the two years. Highest mean concentrations in the reach were measured at station 18, below the Missoula municipal wastewater discharge. Although mean concentrations of total P and N here (Figures 48-49, 52-53) were surpassed by those measured below Deer Lodge, mean bioavailable phosphorus concentrations were the highest found anywhere along the Clark Fork River (Figures 50-51). Nutrient loading data (Figures 72-74) indicate that essentially all of the increase in nutrient concentrations can be attributed to the Missoula WWTP. The Missoula WWTP has been shown to be the largest single point-source of nutrients to the Clark Fork River (Ingman, 1989). The EPA phosphorus criterion was exceeded more than 80 percent of the time at monitoring station 18 during each of the last two years (Figures 68-69). Despite the documented enrichment filamentous algae were never common and algal growths were limited primarily to diatom communities. The quality of the Missoula effluent with respect to nutrients has been relatively constant over the past five years. In May 1989, Missoula County enacted a ban on the sale of phosphorus detergents. This action is expected to significantly reduce levels of phosphorus in the Missoula wastewater discharge.

Nutrient concentrations initially declined with distance downriver from the Missoula WWTP, but the decline was more immediate for P than for N. The large volume Bitterroot River inflow (station 19) was responsible for a significant increase in flow (Figure 2, stations 18-20), a reduction in Clark Fork nutrient concentrations and the frequency at which the phosphorus criterion was exceeded. While the Bitterroot River diluted concentrations of nutrients in the Clark Fork, it added a substantial load of nutrients (Figures 72-73), especially nitrogen, to that already carried by the river.

Another increase in nutrient concentrations occurred between monitoring stations 20 and 22. These stations bracket the Stone Container Corporation kraft mill wastewater discharge. The observed increase in Clark Fork nutrient concentrations was small, especially for nitrogen (Figures 48-55). The Stone wastewater contained relatively high concentrations of nutrients (Figures 64-67) but concentrations which were markedly less than in previous years (Ingman 1989b). The observed instream increase in mean nutrient concentrations from above to below the kraft mill appeared to be smaller than in earlier years (MDHES, 1985; Ingman, 1987). The phosphorus criterion was exceeded more frequently downstream of the Stone discharge (21-36 percent of the time) than upstream (13-27 percent of the time) in FYs 1988-1989. The nitrogen criterion was never exceeded at any middle Clark Fork station during FY 1988-1989 monitoring events.

Toxic levels of ammonia were present in the Stone Container Corporation and Missoula municipal wastewater discharges. However, instream dilution of the effluents prevented problems in the Clark Fork River, even during the lowest streamflows.

From below the Stone Container Corporation mill to the Flathead River confluence, phosphorus and nitrogen concentrations declined as numerous small to medium-sized tributaries added dilution water and as biological assimilation took place. Loads of total phosphorus and nitrogen stabilized while bioavailable phosphorus and nitrogen loads appeared to decline slightly (Figures 72-73), indicating a lack of significant nutrient sources to this reach of the river. The frequency at which the phosphorus criterion was exceeded declined with increasing distance downstream from the Stone wastewater discharge.

The Flathead River more than tripled the volume of the Clark Fork, on the average (Figure 2). Its routinely low nutrient concentrations (Figures 56-63) were responsible for reductions in Clark Fork total phosphorus and total nitrogen concentrations which averaged 35 to 40 percent during each of the last two years. Reductions in bioavailable nutrient concentrations were even larger -- up to 67 percent. However, the Flathead River contributed a larger cumulative load of total phosphorus and total nitrogen to the Clark Fork (Figures 72-73, stations 25 vs. 27) during FYs 1988-1989 than any other point or nonpoint source of nutrients in the entire basin. This fact will be an important consideration if limits on nutrient loading become necessary to preserve the quality of Idaho's Lake Pend Orielle. Nutrient concentrations generally stabilized from below the Flathead River to Idaho (stations 27 to 30) and phosphorus criteria were rarely exceeded (Figures 68-69). Nutrient loads, on the other hand, declined in the reach from above Thompson Falls Reservoir to below Noxon Rapids Dam (Figures 72-73, stations 27 vs. 29). Reductions were noted for loads of total nutrients but not for loads of soluble nutrients. Hence, the primary mechanism by which the reservoirs reduced Clark Fork nutrient loads appeared to be through the settling of nutrient-bearing solids. Cabinet Gorge Reservoir did not further reduce Clark Fork nutrient loads, presumably because most settleable solids were removed upstream. The cause of an apparent increase in nutrient loading through Cabinet Gorge Reservoir (station 29 vs. 30) is unknown.

The nutrient pollution severity scores presented in Figures 75, 76 and 89 give a visual picture of the relative degree of nutrient pollution in the Clark Fork River. Nutrient concentrations most seriously affected three distinct reaches of the river in each of FYs 1988 and 1989. Those areas were the extreme headwaters, the reach below the Deer Lodge sewage lagoon and the short reach of river between the Missoula WWTP discharge

and the Bitterroot River confluence. Impacts appeared to be greater in the headwaters area in FY 1988 and greater below Deer Lodge in FY 1989. Nutrient pollution severity below the Missoula WWTP was comparable in both years. The reaches of river just above Missoula (stations 13-15) and from Superior to the Idaho border (stations 24-30) appeared least impacted by nutrient concentrations. Nutrient impacts during each of FYs 1988 and 1989 appeared to be worse than in years with more normal streamflows, especially in the reaches immediately below the Deer Lodge and Missoula wastewater discharges.

4.4 Suspended Sediment

Following is a review of measured suspended sediment concentrations, estimated suspended sediment loads and sediment pollution severity scores for the Clark Fork Basin during FYs 1988-1989.

Suspended sediment transport in running waters is difficult to quantify accurately, especially in systems as large and complex as the Clark Fork Basin. Although annual loads of suspended sediment have been roughly estimated, it is not an important objective of this program. Our monitoring effort is primarily aimed at establishing ambient concentrations of suspended sediment, quantifying the seasonal and annual variations, establishing the relative severity of the sediment pollution problem and, to the degree possible, identifying major sources of sediment inputs to the river.

In order to assess the relative severity of sediment pollution in the Clark Fork with regard to protecting beneficial water uses, we have to rely on criteria. The emphasis of the water quality assessments in this report have been comparisons to aquatic life criteria because those standards are usually more conservative than standards for other water uses. However, it is a difficult proposition to establish aquatic life criteria for suspended sediment concentrations because impacts are a function of the duration of exposure, as well as concentration. For example, most Montana streams carry appreciable sediment concentrations during the usually short period of spring runoff. Resident aquatic life are adapted to these runoff events and are able to tolerate them. The same conditions sustained over a longer period of time would be devastating.

Our monitoring program is limited in its ability to establish the duration for which measured suspended sediment concentrations prevailed. As a result, we are forced to rely on simpler criteria. The European Inland Fisheries Advisory Council and others have established the following suspended sediment guidelines for the maintenance of freshwater fisheries and associated aquatic life (U.S. EPA, 1973):

Waterbody normally containing suspended sediment concentrations of:	<25 mg/l	High level of protection; no harmful effects.
	25- 80 mg/l	Moderate level of protection; good or moderate fisheries.
	80-400 mg/l	Low level of protection; unlikely to support good fisheries.
	<400 mg/l	Very low level of protection; only poor fisheries.

These criteria have been used as general guidelines for review of the FY 1988-1989 suspended sediment data, with the lowest concentration category (<25 mg/l) providing a single number criterion.

The criteria also provided the basis for the suspended sediment severity scores. The severity scores give a simple numerical rating to identify the reaches of the river that experienced the highest sediment concentrations and most frequently exceeded the criteria.

Silver Bow Creek from Butte to the Warm Springs Ponds can be described as having a moderate to serious inorganic suspended sediment problem, depending on streamflow. Mean concentrations in FYs 1988-1989 (Figures 77-78) were lower than in any previous monitoring year and estimated suspended sediment loads (Figure 85, stations 00-03) were small when compared to other years (Ingman, 1987; 1988c). Annual mean suspended sediment concentrations consistently fell within the high level of protection category at all stations on Silver Bow Creek above the ponds during FYs 1988-1989. However, individual measurements exceeded that criterion as frequently as 27 percent of the time at some sites. Maximum concentrations of suspended sediment occurred during spring runoff and in the winter when drifting ice mobilized considerable quantities of streambed and bank materials. Suspended sediment concentrations, loads and problem severity generally increased from Butte downstream to above the Warm Springs Ponds. Sediment sources within the Silver Bow Creek drainage include an abundance of unvegetated, highly erodible mine tailings -- the same sources which are responsible for much of the documented metals pollution problem. The most important sources of suspended sediment were located between the Colorado Tailings and the ponds. These sources accounted for average inputs of 1100 tons of suspended sediment per year during FYs 1986-1988.

The Butte sewage discharge appeared to be responsible for slight increases in organic suspended sediment concentrations in Silver Bow Creek for several miles below the outfall. However, organic sediment concentrations were usually

only a fraction of the inorganic sediment concentrations which originated from other sources.

The Warm Springs Ponds caused major reductions in Silver Bow Creek suspended sediment concentrations through their function as large settling basins. Estimated total annual suspended sediment loads in Silver Bow Creek during FYs 1988-1989 were reduced two to four fold from above to below the ponds and more than 1000 tons of material was trapped over the two years. Downstream sediment concentrations were a third to a fourth of those above the ponds. From the standpoint of fisheries protection, sediment concentrations in Silver Bow Creek below the ponds generally were good. Concentrations were within the high level of protection range at all times except during March 1989. This event was discussed in the metals section and resulted in untypically high sediment concentrations during one monitoring visit.

Suspended sediment concentrations in the Mill-Willow Bypass and Warm Springs Creek were usually very low during the monitoring period, except for brief periods during the height of spring runoff. At each location, only one measurement during the two year period exceeded the high level of protection criterion. Both of these measurements were made on May 17, 1988 during high flow events. Interestingly, the concentration of suspended sediment in Warm Springs Creek on that date was 137 mg/l, the highest measured at any station during the two years. Warm Springs Creek typically contains some of the lowest suspended sediment concentrations of the stations monitored. It is suspected that streamside smelter waste deposits which are present in the drainage are important sediment and metals sources during high water periods.

Suspended sediment concentrations in the Mill-Willow Bypass during July and August, 1988, following the installation of the ARCO diversion dam, were comparable to July and August, 1987 values.

The range of suspended sediment concentrations in the upper Clark Fork during the monitoring period are shown in Figures 79-80 (stations 07-15). The trend indicated was one of general increases in concentrations and reduced fisheries protection from the headwaters downstream to station 10, the Clark Fork above the Little Blackfoot River, or to station 12, the Clark Fork at Bonita, depending on the year. The suspended sediment load plots (Figure 85) demonstrate that Clark Fork sediment loads increased dramatically from the headwaters region downstream to station 13, Clark Fork at Turah, indicating the presence of sediment sources.

The worst reach from the standpoint of fisheries and aquatic life protection was from Deer Lodge to Bonita (Figures

86-87). Sediment concentrations exceeded the high level of protection criterion from 27 to 36 percent of the time during FYs 1988-1989. Streamside tailings deposits and unstable streambanks throughout the upper Clark Fork were the probable causes. It should be noted that measured sediment concentrations and estimated sediment loads in this reach of river during FY 1988 were comparable to those for FY 1987 but were only a quarter of those in FY 1986. Consequently, the prevailing drought of recent years has been responsible for decreased instream suspended sediment concentrations and sediment transport. On the contrary, the infrequency of "flushing flow" events have led to the buildup of substrate-smothering, fine-grained bottom sediments at some locations such as station 11, the Clark Fork at the Gold Creek Bridge.

Rock Creek, located between monitoring stations 12 and 13, is a large tributary that normally carries low concentrations of suspended sediment. Mean concentrations downstream of Rock Creek were measurably less during both monitoring years. Conditions were also more favorable from the standpoint of fisheries protection.

Downstream from Station 13 the Blackfoot River joins the Clark Fork. This large stream nearly equals the Clark Fork in size and its suspended sediment concentrations (Figures 81-82) averaged about half of those in the Clark Fork above the Blackfoot. Its inflow probably helps to reduce Clark Fork sediment concentrations on the average even though a large sediment trap exists at the confluence of the two streams -- the Milltown Dam and Reservoir. Milltown Reservoir reduces Clark Fork sediment concentrations during part of each year. However during high flow events and during past operational drawdowns or construction activities, the settled sediments in the reservoir were mobilized and transported downstream. The reservoir is a significant sediment source in those instances. The dam spillway was reconstructed in 1988. Improvements in its design will eliminate the operational drawdowns of the past.

During the low streamflows of FY 1988, Milltown Reservoir effectively trapped some 10,000 tons of suspended sediments originating in the upper Clark Fork and Blackfoot drainages. Mean suspended sediment concentrations in the Clark Fork below Milltown Dam were comparable to those in the Blackfoot River. During summer 1988 (FY 1989) reconstruction of the Milltown Dam powerhouse created temporary turbidity and sediment problems in the Clark Fork below the dam. During FY 1989, mean suspended sediment concentrations in the Clark Fork downstream of the dam were slightly higher than upstream Clark Fork concentrations. Although sediment load data are not yet available, it is suspected that Milltown Reservoir acted as a net sediment source in FY 1989.

Organic suspended sediment concentrations were generally low throughout the upper Clark Fork and averaged a small fraction of the total sediment concentration. The Deer Lodge sewage discharge appeared to cause measurable though small increases in Clark Fork organic sediment concentrations for several miles downstream of the discharge.

During most years, suspended sediment concentrations in the middle Clark Fork from Missoula to the Flathead River (Figures 79-80, stations 16-25), generally decrease in a downstream direction as a result of additional dilution from cleaner incoming tributaries, such as the Bitterroot River (Ingman, 1988c). Concentrations normally fall in the high level of fisheries protection category, with those frequencies increasing with distance from Missoula. During FYs 1988-1989, the trend was different. Mean suspended sediment concentrations were roughly equal throughout the reach, while maximum concentrations were highest in the middle of the reach. The prevailing drought probably accounted for the relatively stable and low average concentrations. The fact that peak concentrations were recorded in the middle of the reach resulted from ever-changing conditions during spring runoff. Because each monitoring run took several days, our monitoring happened to catch higher suspended sediment concentrations at some stations than others, depending on where we were at in relation to moving "slugs" of runoff water and peaks in flow.

Suspended sediment load plots (Figure 85, station 18 vs. 20) point to the Bitterroot River as the most significant sediment source to the middle Clark Fork. The Missoula WWTP and especially the Stone Container Corporation wastewater discharges contained significant concentrations and loads of largely organic suspended sediment (Figures 74, 83-84). However their influences on river organic suspended sediment concentrations and loads were not measurable due to high background concentrations and loads.

Suspended sediment concentrations in the lower Clark Fork (Figures 79-80, stations 27-30) began low and declined further. The Flathead River more than doubles river volume in the lower Clark Fork and usually carries a lower suspended sediment concentration (Figure 81-82). As result, suspended sediment concentrations in the Clark Fork downstream of the Flathead are reduced most of the time and nearly always fall within acceptable levels for fisheries protection. An exception to this general pattern frequently occurred during late winter or early spring. Kerr Dam below Flathead Lake controls streamflows in the lower Flathead River. It is a peaking-power hydroelectric facility which means that most discharge from the dam occurs during periods of peak power demand. The result is that streamflows and river stages in the lower Flathead River fluctuate on a 24-hour basis. During winter, these fluctuating

water depths cause large volumes of ice to accumulate along the river banks. When significant midwinter or early spring thaws occur, these large rafts of ice flush out. In the process, suspended sediment concentrations become elevated as shoreline areas and the river bottom are scored by these icebergs. Such events occurred in February 1988 and March 1989. On these occasions, the Flathead River significantly increased the suspended sediment concentrations in the Clark Fork River.

Further downstream, the Noxon Rapids Reservoir, and to a lesser extent Thompson Falls Reservoir, acted as settling basins for Clark Fork sediments and were responsible for significant reductions in Clark Fork suspended sediment concentrations. The last reservoir in the system, Cabinet Gorge Reservoir, had no apparent effect, presumably because most of the settleable solids had already been trapped upstream. In general, water quality in the lower Clark Fork was excellent from the standpoint of suspended sediment concentrations during FYs 1988-1989, largely as a result of dilution by the Flathead and the influences of hydroelectric impoundments. Lowest suspended sediment concentrations were found in the reach from below Thompson Falls Dam to Idaho.

Suspended sediment load plots (Figure 85) point to the Flathead River as a major source of sediment to the lower Clark Fork. In fact, its contribution was larger than that of the Clark Fork above the Flathead River confluence, despite the Flathead's routinely lower suspended sediment concentrations. The lower Clark Fork Reservoirs were responsible for reductions in Clark Fork sediment loads that were larger than the total load contributed by the Flathead. Suspended sediment loads in the Clark Fork at the Idaho border were about half of those carried by the Clark Fork above the Flathead River confluence.

The suspended sediment severity scores for the entire mainstem Clark Fork (Figures 86-87) indicate that the reach of river from Deer Lodge to the Rock Creek confluence was most impacted by suspended sediment during the past two monitoring years. Best conditions, relative to protection of fisheries and aquatic life, were found from below Noxon Dam to the Idaho border. Clark Fork water quality, from the standpoint of suspended sediment concentrations, was slightly better in FY 1988 than in FY 1989 due to predominantly lower streamflows and less sediment production and transport. Conditions were much better overall in FYs 1988 and 1989 than in higher flow years, such as FY 1986, due to less runoff, erosion and sediment transport.

5. CONCLUSIONS

Based on the previous discussions of monitoring results, the following general conclusions can be made about water quality conditions and pollutant sources in the Clark Fork Basin during state fiscal years 1988 through 1989.

5.1 Streamflows

Drought conditions prevailed throughout much of the Clark Fork Basin for most of the two-year monitoring period. Due to low streamflow conditions, suspended sediment and metals concentrations and loads were smaller than in previous years. Nonpoint-source contributions of nutrients stemming from land use activities and streambank erosion were also smaller due to the drought and had less of an influence on Clark Fork nutrient concentrations. Conversely, point-source municipal and industrial discharges had a more pronounced effect on river nutrient concentrations during the monitoring period due to the low streamflows and subsequently lower dilution of the wastewaters.

Streamflows in the headwaters of the Clark Fork were but a fraction of those in the middle and lower Clark Fork. Tributary inflows, especially those of Rock Creek and the Blackfoot, Bitterroot and Flathead rivers, greatly increased the size of the Clark Fork. The Flathead River more than tripled the volume of the Clark Fork, on the average. Increased dilution of pollutants below tributaries was an important factor in determining Clark Fork water quality conditions.

5.2 Metals

Silver Bow Creek above the Warm Springs treatment ponds was grossly polluted with toxic levels of copper, zinc, cadmium and lead. The highest metals concentrations in the Clark Fork Basin were measured here. Sources of these metals included three equally important areas: the Colorado Tailings area, mine tailings and/or contaminated groundwater inputs in the reach from below the Colorado Tailings to the Warm Springs Ponds, and uninvestigated sources to upper Silver Bow Creek. Each of these areas contributed more than 10 tons of copper and zinc to Silver Bow Creek in one year.

The Warm Springs treatment ponds were extremely effective at reducing toxicity and concentrations and loads of metals in Silver Bow Creek and the Clark Fork River. Most of the Silver Bow Creek metals load was trapped in the ponds and metals concentrations were generally an order of magnitude less than above the ponds. However, metals criteria for the protection of aquatic life were exceeded fairly regularly. The ponds were not as effective at reducing concentrations of lead as for other

metals. Metals removal efficiencies of the Warm Springs Ponds were about twice those of previous years due to longer retention times associated with low streamflows. Quality of the pond system discharge was poorest in winter and spring, due to reduced treatment when the ponds were ice-covered, or shortened retention times and elevated influent metals concentrations associated with high flows. Metals concentrations in the pond discharge in March 1989 were among the highest ever measured, following a rapid thaw in the Silver Bow Creek drainage when the ponds were still under ice.

Metals concentrations in the Mill-Willow Bypass were roughly comparable to those in Silver Bow Creek below the treatment ponds. Highest metals concentrations in this stream followed rains or thaw events, as streamside tailings material was mobilized. The highest arsenic concentrations in the monitoring network were measured here. The lowest metals concentrations were measured in July and August 1988, when a temporary diversion dam was installed upstream below most of the tailings in the channel.

Warm Springs Creek was important from the standpoint of diluting metals concentrations in the Clark Fork and increasing water hardness. Metals concentrations in this creek were usually very low, except during very high flows, when streamside smelter wastes presumably were washed in. Warm Springs Creek suffered from severe agricultural dewatering during summers.

The mainstem Clark Fork, from its headwaters to the Little Blackfoot River confluence, exhibited fair to poor water quality relative to metals concentrations. Highest instantaneous metals concentrations were recorded at the upper end of this stream reach, indicating the potential for acutely toxic events. Highest mean concentrations occurred at the lower end of the segment, suggesting more chronic impairment there. Chronic toxicity criteria for metals were exceeded nearly half the time in the Deer Lodge area.

The most important sources of metals to the Clark Fork during the two-year period were streamside and stream channel tailings deposits located between Warm Springs Creek and the Little Blackfoot River.

Dilution by numerous, large clean tributaries and increasing distance from metals sources were responsible for progressively improving water quality below Garrison. Exceedences of aquatic life toxicity criteria for metals were infrequent, slight and short-lived in the river below Missoula and rare below the Flathead River.

A localized exception occurred below Milltown Dam during summer 1988. Reconstruction of the powerhouse caused

temporary downstream increases in metals concentrations but exceedences of aquatic criteria were not measured. Milltown Reservoir appeared to be an effective metals sink during low streamflow years such as FY 1988.

Of the three wastewater discharges monitored, two exhibited periodically high concentrations of metals. The Butte WWTP discharge frequently contained elevated concentrations of copper and zinc, presumably as a result of infiltration of metals-contaminated groundwater into sewer mains. Shallow groundwater at the Butte WWTP also had to be pumped from time to time and during these events, the discharge contained concentrations of zinc greater than those in Silver Bow Creek. The Missoula WWTP discharge occasionally showed elevated concentrations of copper which probably resulted from copper plumbing throughout the city. However, dilution in the Clark Fork was more than adequate to prevent instream toxicity problems.

Overall, the metals pollution problem in the Clark Fork River was less severe in FYs 1988 and 1989 than in earlier years with more normal streamflows.

5.3 Nutrients

Silver Bow Creek above the Warm Springs Ponds was polluted with excessive levels of algal nutrients at all times. Nutrient concentrations were an order of magnitude larger than at all other monitoring stations in the Clark Fork Basin. The source of those nutrients was the Butte WWTP discharge and the problem was inadequate dilution. Criteria for the prevention of nuisance algal growths were routinely exceeded, but elevated metals concentrations were effective at limiting their development. Toxic levels of ammonia were also a frequent problem in Silver Bow Creek from the sewage outfall to the Warm Springs Ponds.

The Warm Springs treatment ponds were very effective at reducing nutrients concentrations and loads in Silver Bow Creek and the Clark Fork River. Concentrations and loads below the ponds were one-fourth to one-sixth of those above. Nutrient removal efficiencies of the ponds were slightly higher than in previous years, presumably as a result of longer hydraulic retention times associated with the prevailing low streamflows. Despite the improved quality, nitrogen criteria were frequently exceeded and phosphorus criteria were almost always exceeded.

The Mill-Willow Bypass and especially Warm Springs Creek had lower nutrient concentrations than Silver Bow Creek below the Warm Springs Ponds. Each of these tributaries helped to dilute nutrient concentrations in the mainstem Clark Fork.

However, the Mill-Willow Bypass had elevated concentrations of nitrogen when compared to Clark Fork tributaries other than Silver Bow Creek. Sources of nitrogen there may have been associated with groundwater inputs from the unsewered Opportunity area.

Nutrient concentrations in the upper Clark Fork, from the headwaters to Missoula, generally declined with increasing distances from wastewater discharges and below incoming tributaries. Mean nutrient concentrations increased downstream from the Deer Lodge municipal wastewater discharge and were among the highest found anywhere in the mainstem Clark Fork. Phosphorus concentrations in the upper Clark Fork downstream to Rock Creek routinely exceeded the criterion to prevent nuisance algae. In the absence of the extremely high metals concentrations of Silver Bow Creek, filamentous green and diatom algae proliferated. A primary source of phosphorus was the Deer Lodge WWTP discharge. Nitrogen criteria were generally not exceeded in the upper Clark Fork and sources were more diffuse. They included the Deer Lodge WWTP and numerous tributaries in the Deer Lodge Valley which were impacted by land use activities.

Rock Creek and the Blackfoot River provided large volumes of clean dilution water. Nuisance filamentous algae were largely curbed below these tributaries.

Nutrient concentrations in the middle Clark Fork, from Missoula to the Flathead River, were smallest at the upper-most and lower-most ends of the reach. Highest concentrations were found in between, in the area immediately below the Missoula municipal wastewater discharge, and to a lesser extent, below the Stone Container Corporation wastewater discharge. Phosphorus concentrations in the river between the Missoula WWTP and the Bitterroot River usually exceeded the criterion to prevent nuisance algal growths. However, filamentous algae were never common and algal growths consisted primarily of diatoms.

Concentrations of nutrients in the Missoula wastewater discharge were comparable in each of the last five years.

The Missoula and Stone discharges contained high levels of ammonia-nitrogen. High dilution rates in the river appeared to prevent instream toxicity problems downstream of these discharges.

The lower Bitterroot River reduced concentrations of nutrients in the Clark Fork through dilution but contributed large loads of nitrogen to the middle river. The Missoula WWTP was clearly the most important point-source of nutrients in the

entire Clark Fork Basin. Concentrations of nutrients in the Stone Container Corporation wastewater were far less than in earlier years, reflecting in-plant nutrient reduction measures over the last four years.

Nutrient concentrations steadily declined from below the Stone Container Corporation wastewater mixing zone to below Thompson Falls or Noxon Rapids dam, where lowest levels were measured. Nutrient criteria in the lower Clark Fork were infrequently exceeded.

The Flathead River contributed a larger cumulative load of total phosphorus and total nitrogen to the Clark Fork than any other source in the basin. However, its large volume and low nutrient concentrations reduced Clark Fork nutrient concentrations by about a half.

Thompson Falls and Noxon Rapids Reservoirs acted as sinks for a considerable portion of the total nutrient load carried by the lower Clark Fork River. On the other hand, bioavailable nutrient loads did not appear to be affected by the reservoirs. Total nutrient loading from the Clark Fork River to Lake Pend Oreille was within the range of loads computed for earlier years.

In general, nutrient problems were more severe in the Clark Fork River in FYs 1988 and 1989 than in earlier years due to the decreased availability of dilution water in the river downstream of wastewater discharges.

5.4 Suspended Sediment

Suspended sediment concentrations in Silver Bow Creek above the Warm Springs ponds can be described as problematic at best. Conditions were generally poorer with increasing distance from Butte. Concentrations were highest during spring runoff and in winter when ice flows scoured streambeds and banks. Sediment sources in the form of unvegetated mine tailings were widespread throughout the drainage.

The Warm Springs pond trapped the majority of the Silver Bow Creek sediment load and sediment concentrations below the ponds were favorable from a fisheries standpoint.

Suspended sediment concentrations in the Mill-Willow Bypass and Warm Springs Creek were low, except during high streamflows.

Suspended sediment concentrations in the upper mainstem Clark Fork generally increased downstream to the Little Blackfoot River or Rock Creek confluences, depending on the year. The Clark Fork from Deer Lodge to Rock Creek was considered the

poorest mainstem reach from the standpoint of fisheries and aquatic life protection. Streamside tailings deposits and unstable streambanks were the likely sediment sources.

Below Rock Creek, suspended sediment concentrations were significantly more favorable from the standpoint of maintaining good fisheries.

Suspended sediment concentrations in the Blackfoot River averaged about half of those in the Clark Fork below Rock Creek.

Milltown Dam and reservoir acted as a sediment trap during FY 1988 and served to reduce downstream Clark Fork suspended sediment concentrations and loads. Dam powerhouse reconstruction activities in FY 1989 created temporary turbidity and sediment problems downstream of the dam and the reservoir acted as a net sediment source.

The middle Clark Fork had generally acceptable suspended sediment concentrations as a result of additional dilution from tributaries such as the Bitterroot River. Conditions were comparable throughout the reach from Missoula to the Flathead River confluence. The Bitterroot River generally contained lower suspended sediment concentrations than the Clark Fork. However, that drainage appeared to be the most significant source of sediment inputs to the middle Clark Fork. The Missoula WWTP and especially the Stone Container Corporation discharged large quantities of largely organic suspended sediment to the middle Clark Fork. However, dilution of the wastewater discharges and background sediment concentrations in the river were sufficiently high to make their influences negligible.

The Flathead River was responsible for a significant reduction in lower Clark Fork suspended sediment concentrations, on the average. An exception occurred during early spring runoff when accumulated shoreline ice flushed out and scoured the river banks and bed. The ice deposits appeared to be the result of fluctuating water levels associated with the operation of Kerr Dam. When ice flushing occurred, sediment concentrations were high in the Flathead River and in the Clark Fork below the Flathead.

The Clark Fork from below the Flathead River to Idaho generally contained excellent quality water from the standpoint of suspended sediment concentrations. Thompson Falls and Noxon Rapids Reservoirs reduced Clark Fork suspended sediment concentrations and loads four to five fold. Cabinet Gorge Reservoir had no apparent additional effect.

The best conditions in the basin relative to suspended sediment concentrations were found from below Noxon Dam to the Idaho Border. Estimated annual suspended sediment loads below Cabinet Gorge Dam (just above Lake Pend Oreille) were about half of those carried by the Clark Fork above Flathead River. The largest source of sediment to the lower Clark Fork was the Flathead River drainage.

Overall, water quality in the Clark Fork with respect to suspended sediment was better in FYs 1988 and 1989 than in other years due to less runoff, erosion and sediment transport.

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